MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 57 NUMBER 12

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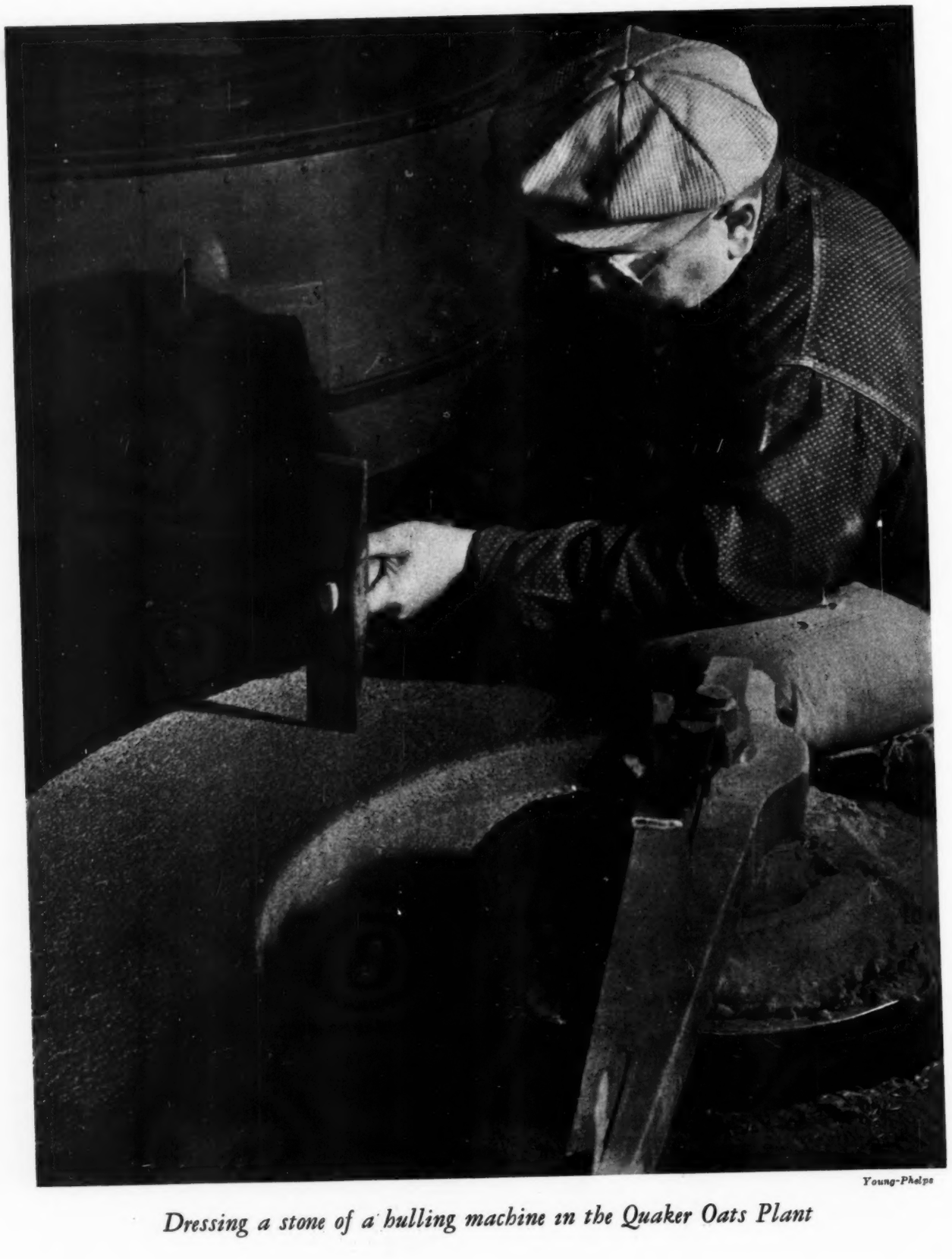
Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., und r the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Copyrighted 1935, by The American Society of Mechanical Engineers.



Young-Phelps

Dressing a stone of a hulling machine in the Quaker Oats Plant

VOLUME 57
No. 12

MECHANICAL ENGINEERING

DECEMBER
1935

GEORGE A. STETSON, *Editor*

The Automobile Portent

AN ENGINEER'S interest in this year's automobile lies not so much in the assemblage of sleek streamlined motorcars on display at the Grand Central Palace as in the designing rooms and shops in which they were made. Few radical departures in the cars themselves call for comment; but a sense of the powerful and effective engineering organizations that make it possible to place into the possession of individuals such beautiful pieces of mechanism is inescapable.

In fact, the prime significance of the show was economic, rather than technical, and the temptation is great to deal at length with this phase of it. To the amazement and gratification of the manufacturers the public responded splendidly in orders for the new models and to an extent that has set commentators in all branches of business the task of offering explanations.

Just what the change of date from January to November will accomplish none can safely predict. It is hoped that better stabilized production schedules will result, and if they do, the economic life of the country from management to labor will be greatly benefited.

The automobile industry has been conspicuous in leading the country out of the depression, and at present the courage of those who guessed the time ripe for expanding business is well vindicated. Just where the money comes from is hard to say, but it must be remembered that several lean years have reduced the number of new cars normally sold and deferred replacement of older vehicles which are due for retirement. A writer in the New York Times *Annalist* estimates the annual potential domestic market at 5.4 million cars for the next three years.

Another factor to which weight must be given is our growing dependence on the motor car. Because of the automobile, a decentralizing movement of populations took place during the lamented twenties that resulted in the growth of suburban homes. Even dwellers in rural communities accustomed themselves to greater dependence on commercial and recreational centers, and found the automobile had many advantages over the horse. The mobility that the motor car provides is not willingly given up, and sacrifices in other lines will be made by many to retain it, even if the automobile does not represent a downright necessity for a mode of life.

Considerable emphasis is being placed by manufacturers on the safety features of today's car. This is a commendable display of good sense and a tacit acceptance on the part of the industry of a social responsibility it bears. Statistics of motor-car accidents make unpleasant reading for every one; and while, in the last analysis, it is the driver who must shoulder the blame, everything should be done to remove as many contributory causes of accidents as possible. Hence the safety features of brakes and body construction are properly emphasized, rather than speed. For while speed itself is not necessarily dangerous, the ability to drive a heavy vehicle faster than good common sense admits is wise under given conditions of road and traffic tempts fools to become murderers and offenders against the rights, safety, and property of others.

It is trite to say that the automobile is the symbol of our modern life, yet the industry that produces it has made such far-reaching social and economic changes in our civilization that the subject is a fascinating one to ponder. Those in the industry have displayed such remarkable leadership and so much good sense in the conduct of their own affairs and their relations with the public that they inspire the hope that our industrial civilization may not be the dust and ashes that some of our melancholy prophets pronounce it.

What Carnegie Made Possible

IT WOULD be ungracious to pass over the one-hundredth anniversary of the birth of Andrew Carnegie without calling attention to the unique and generous contribution he made to the engineering profession more than a quarter century ago.

A profession, to be effective in service to its own interests and those of society, requires organization, and organizations require a habitation as well as a name. From his personal fortune, amassed in an industry to which engineering has made conspicuous contributions, Mr. Carnegie provided the funds with which the Engineering Societies Building and the Engineers' Club in New York were built.

As a result of Mr. Carnegie's gift the major national engineering societies were brought together in such a manner that their common interests were emphasized and given an opportunity for growth. Living under the same roof and administering a common property, the societies found less concrete and more significant interests than their headquarters and public meeting places, and over the intervening years have developed a number of joint activities by means of which they increase in national prestige and in their services to the

profession. The engineer's debt to Andrew Carnegie grows as the years multiply the number of endeavors in which there is common action increases.

It is no detraction from the credit due to Andrew Carnegie to recall that the spirit of society cooperation which he made a vital force sprang from the high ideals for the profession held by the late Calvin W. Rice and Charles F. Scott. It was they who convinced Mr. Carnegie of the immense service he could render the engineering profession by making it possible for the societies to live together in a single building. And it is appropriate also to recall that latest of all the common interests in which these societies have joined, the Engineers' Council for Professional Development, was an even greater flowering of that spirit of cooperation for public and professional good, because, in this most recent endeavor, there has been enlisted the support of the Society for the Promotion of Engineering Education and the National Council of State Boards of Engineering Examiners. There have thus been drawn into the joint activities of engineers groups representing the educational and legal phases of the engineer's life, as well as those whose chief concern is professional and technological development.

Carnegie's gift implemented the vision of Rice and Scott and their associates. Engineers will do well not to forget this in acknowledging the contribution of money which made their common headquarters possible.

The Engineer as a Citizen

GOOD government needs the intelligent support of all the loyal friends it can muster. Socrates discoursed on this theme nearly twenty-five centuries ago. The men of his time and city made some considerable advances in the philosophy and practice of government. The responsibility of the individual citizen was a highly prized privilege that set him apart from barbarians and slaves, as it has ever since. Such privileges are difficult to win and just as difficult to maintain. Indifference, corruption, widespread disaster, and dissatisfaction lead to gradual or revolutionary usurpations of freedom and the popular will. The complications of changing conditions, increased by the rise of technology, make impracticable the simpler forms of government, and bring together in closely interdependent groups individuals whose traditions and methods of thought are not easily reconciled. The people fall prey to venal public servants, to stupid bureaucracies, and to the dictatorships of individuals and minorities.

Today the almost complete disappearance of the town meeting has removed men from that personal contact with local public affairs that made our fathers so competent to deal with the problems of the community. There is less practical appeal in concern for such matters when elected and appointed civil servants have taken over so much of the detail that affects us vitally but too frequently indirectly. Developments in this country and particularly abroad bear witness, however, to the urgent need for a rebirth of that interest of the individual in civic and national affairs without which free institutions cannot persist for long. Hence, any movements that call us back to our obligations and responsibilities as citizens and train us to assume them more manfully are significant and worthy of encouragement. Attention is therefore directed to two concrete evidences of what engineers are trying to accomplish along this line, to be found in the work of the American Engineering Council and in classes in citizenship at the Newark College of Engineering.

Elsewhere in this issue, page 814, brief mention will be found of a meeting of the subcommittees of the Public Affairs Committee of the American Engineering Council, held in Washington early in November. Mr. Feiker, as executive secretary of the Council, has put his forceful personality behind this public-affairs movement, to the credit of the A.E.C. and the engineering profession. How effective the engineer's concern with public questions may become cannot be predicted, but there is abundant evidence that this concern should be great. The technological functions of government and the public service increase with amazing rapidity. An unbelievable percentage of engineers is to be found on the public payroll. Services of public and quasi-public nature engaged the attention of many others. Even those who profess to practice engineering find themselves subject to the police power of their states, as reference to Dean Daggett's summary of engineers' registration laws, published in this issue, will prove. If the good sound sense that engineers must apply to their technical problems can be brought to bear on the less scientific questions of public affairs, well and good. But the temptations must be avoided of overdoing class consciousness, overexalting the engineering approach to the subtler problems involving human relationships, and taking the wrong course because of narrow views and ignorance of many nonengineering factors.

The second example involves the principle of training the individual. Some months ago, Dean Cullimore, of the Newark College of Engineering, wrote in MECHANICAL ENGINEERING about the course in citizenship conducted at that institution by Roy V. Wright, past-president of The American Society of Mechanical Engineers. The syllabus of this course is contained in a modest pamphlet of Mr. Wright's authorship entitled, "The Engineer's Duty as a Citizen." Mr. Wright conducts this course on the discussion method. Assignments in the pamphlet are thrashed out in the classroom where points of view can be expressed and criticized and questions brought forth for consideration. Actual experience as a freeholder of the State of New Jersey gives Mr. Wright a practical slant for his contributions to the discussion. All who know Mr. Wright or who have seen his little pamphlet can testify that there is practical idealism as well as practical politics in his views. At a time when old ideas are being so carelessly thrown out of the window to make way for new ones, men like Mr. Wright can perform a very real service by directing the discussions of youth to the hoped-for truth. More of them should be engaged in such work.

Desired Characters of SURFACE FINISHES

By J. E. KLINE

THE CARBORUNDUM COMPANY, HUTTO MACHINE DIVISION

IT IS common knowledge that the finish possessed by contacting surfaces has a decided effect upon the coefficients of static and kinetic friction. Yet accepted formulas for friction deal only with weight, coefficient of friction, and force applied, without regard for speed or area of contact, much less for surface finish. It is well known, however, that static friction and kinetic friction are quite different, and a study of both phases of friction is important, particularly where lubrication is dependent upon certain types of motion for its sustenance. In the past, no attempt has been made to define either the type or the character of these mating surfaces, although it is obvious that these factors modify the friction factor, just as a lubricant does.

Offhand conceptions of finish are sometimes misleading, particularly when considered from the point of view of their frictional values. Gage blocks, for example, possess better than customary industrial surface finishes, but when rubbed together without lubrication, their frictional resistance to movement upon one another rapidly increases the more they are rubbed. This effect, it might be conjectured, is the result of the increase in pressure caused by the exclusion of the atmosphere from their contacting surfaces. The tremendous frictional resistance set up, on the other hand, is hardly accounted for by a bearing pressure of 15 lb per sq in. If the contacting surfaces are lubricated, however, the frictional resistance immediately decreases, even if the blocks are artificially loaded to the equivalent of atmospheric pressure, thus forcibly illustrating the value of lubrication.

Why is it necessary to consider lubrication in a discussion of surface finishes? Because lubrication is a requisite in mechanics, not because of, but in spite of, anything we have been able to do with respect to precisely finished surfaces.

MOLECULAR STRUCTURE OF SURFACES

All materials are molecular in structure. These infinitesimal bodies are conceded to be generally globular in shape, and hence cannot be crowded together with no space between. A cubic inch of steel weighs 0.286 lb, but this weight in steel balls could not be placed into a one-cubic-inch box unless the balls were as small in diameter as steel molecules.

Let us assume that we have accomplished the molecular-ball cramming feat previously mentioned and have succeeded in holding them in place for further processing. We thereupon proceed to grind, lap, hone, or polish away a sufficient amount of the protruding surface balls to produce the finest surface possible. Now let us assume an identical cube of some dissimilar metal, such as brass, iron, babbitt, or bronze. We find that the molecular "balls" comprising this other metal are of a different size from those of steel, also that they respond differently to the grinding and polishing operations. By bringing into contact the polished surfaces of these structures with a rubbing motion, we are duplicating what occurs in equally well machined and finished solid objects.

Both the imaginary cube and a real, solid-metal cube possess not a solid contact surface, but rather a surface of flattened balls that cannot turn. The similarity or dissimilarity in structure of the molecules comprising the two surfaces prevent or increase the possibility that one will slide upon the other with reduced friction, largely as a result of the failure of the molecules to "mesh." If they did mesh exactly, shearing of some of the balls would occur upon relative movement of the cubes. This is what actually occurs when dry surfaces seize. Metal forcibly removed from one piece literally becomes part and parcel of the other, increasing the disfigurement of the latter with consequently increased capabilities for its scoring effect upon the former.

FUNCTION OF A LUBRICANT ON A SURFACE

In any event, the presence of a lubricant is extremely advantageous, as oil itself is a molecular structure interposed between the contacting surfaces and becomes a ball-bearing medium. Inasmuch as a ball will not roll across a groove as wide as its diameter and more than one-half its diameter in depth, it is apparent that roughly finished surfaces are not satisfactorily lubricated with lubricants of fine structure. With this conception in mind, finely finished surfaces can be considered not so much as bearing surfaces, but as "races" on which the molecules of lubricant roll. It is generally conceded that properly fitted and lubricated working parts never touch each other while in operation, but are held in spaced relation by the lubricating film.

Most liquids and some nonmetallic solids, like graphite or soapstone, are lubricants to a greater or less degree. Each class of lubricant has its peculiarities and adaptabilities. Some are decidedly viscous, but are relatively low in lubricating value or "oiliness," whereas others possessing practically no "body" are remarkably oily. While it is true that the viscosities of lubricants bear no definite relationship to their oiliness any more than does the hardness of a material determine its wearing qualities, perhaps subconsciously we have been of the opinion that a lubricant must have an inherent tenacity to "stay put" in order to maintain unbroken its protective film between working parts.

This matter of lubrication leads to the controversial subject of what constitutes a finished surface, for the surface is what the oil film is attached to. What is needed is a broader conception of the relation of surface finish to lubrication. One cannot be considered without appreciation of its effect upon the other.

PRODUCTION OF SURFACE FINISHES

The goal of modern manufacturers has been, and to a large extent still is, the production of perfectly smooth surfaces by artificial means. Toward this end, attempts have been made to produce surfaces that are practically perfect, being within five millionths of an inch dead smooth, and with

Contributed by the Machine Shop Practice Division and presented at the Annual Meeting, New York, N. Y., Dec. 2–6, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

a remarkable ability for reflection. In fact, they are initially better than they eventually become in operation, no matter how carefully the natural run-in may have been made.

Fig. 1 shows quantitatively just what is meant by the last sentence. Two surface records, or profilograms, are shown. These graphs were made by a profilograph, an experimental measuring instrument developed by Prof. E. J. Abbott, of the University of Michigan. In this machine, a specimen of the surface to be measured is traversed under a sharp-pointed diamond, which follows the profile of the surface. The movements of the tracer point are amplified by a tiny mirror and recorded on a strip of sensitized paper. Irregularities down to 10 millionths of an inch in height can be measured with reasonable accuracy, and irregularities of 1 or 2 millionths can be detected in very smooth surfaces. These two particular graphs are purely relative and do not represent the magnified contours, as the vertical scale is 66.7 times the horizontal.

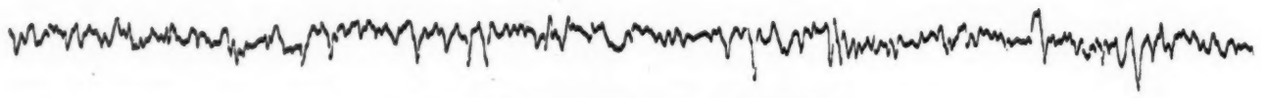


FIG. 1 PROFILOGRAPH RECORDS OF TWO SURFACES

(Upper curve, cylinder bore honed to a smooth finish. Lower curve automobile cylinder wall carefully run-in and used.)

The upper curve of Fig. 1 shows the nearest thing to productive mechanical perfection—the circumferential surface of a cylinder bore honed to a smooth, highlighted finish. The lower curve shows a corresponding surface of an automobile cylinder wall that has been carefully run-in and used. There is literally "no comparison" between the two, yet it is obvious that the upper surface will revert to the lower surface in use. From this point of view alone, it often seems superficial to attempt to produce too perfect a surface. Later on it will be shown that there are other disadvantages in the highlighted surface.

"TYPE" AND "CHARACTER" OF SURFACES

Actual use of these mechanically perfect surfaces has revealed that the *type* of surface is not as important effectually as its *character*. Just as the character of man is molded by heritage and environment, so also is the character of a surface formed by the tools that shaped it, or gave it birth, and lastly by its contact with contiguous surfaces.

It is acknowledged that the cutting of materials in any manner leaves a mark, or rather a multitude of marks, to record the disturbance of the molecular structure of the material. These marks follow the path of the cutting tool, whether the displacement of the material is accomplished by boring, reaming, broaching, grinding, honing, lapping, or kindred methods. Opticians tell us that the horny cells of the skin in the human finger will produce a scar of measurable depth when drawn across the surface of a highly polished lens. Microscopic examination of the most highly finished surfaces yet produced will disclose the direction of the movement used to obtain the finish. This directional marking we choose to call the *character* of the surface.

When surfaces of like character are engaged with each other, the *type* of finish they possess is of lesser importance. A practical demonstration of this fact may be accomplished by subjecting a new deck of playing cards to a twisting action while pressure is applied upon the top of the pack. The deck will divide at some one point and will do so repeatedly between the same two cards. This identically repetitive split occurs because the initial scoring effect produced between these two cards has developed *affinitive* surfaces upon their contacting parts. A microscopic examination of these affinitive surfaces would show them to be infinitely rougher than those of other cards in the deck. Yet the fact that they rotate more freely upon one another is sufficient evidence that the coefficient of friction between them is less than between the relatively smoother surfaces of the other cards. A reproduction of this experiment using a stack of polished steel plates again substantiates the value of affinitive surfaces versus those possessing technically smoother surfaces.

In approaching the problem of surface finish in the light of character, rather than quality or type, it is obvious that directional movement plays a predominant part in the result. Is it not logical then, when attempting to produce surfaces that are to be subjected to annular directional contact with their mating parts, that some endeavor be made to produce these surfaces with the finish markings as nearly as possible in the direction in which the run-in markings lie when wear has occurred? Similarly, if the parts are to be subjected to longitudinal motion in operation, identical advantages will be realized if the marks, however minute, of the finishing operation are correctly disposed with respect to the direction of motion when the part is in use.

Simple proof of the mechanical and practical advantages of surface character may be obtained by comparing the coefficients of friction and wear of two surface-ground objects when moved longitudinally and transversely upon one another with respect to the markings made upon their surfaces by the grinding wheel. Furthermore, convincing evidence of the fallacy of "visual calibration" of surface finishes may be had by comparing the appearance of a "finely ground" surface viewed across and along the wheel markings. In the former instance, the surface appears to possess high reflective qualities, whereas in the latter it does not because of the wheel markings which are now visible.

Actually, a number of manufacturers have already adopted corrective marking operations with remarkable improvement in product efficiency. Surface-finish calibrations arbitrarily established as the engineering ideal have become of less importance. Excellence of reflecting qualities is no longer a factor with these manufacturers. They now pay little attention to the appearance of surfaces, but rather concentrate their efforts on obtaining improved performance, which, in the final analysis, is the goal we all seek. Examples from actual practice will illustrate the old and the new conceptions of proper finish for running parts.

HONED SURFACES

The hone or abrasive stick-type grinder is the currently accepted tool for finishing cylinder bores, whether they be for automobile engines or compressors. Yet there is strong disagreement as to the character of surface the hone should be required to produce. For the same purpose, one manufacturer may use 100-grit and another 500-grit stones. Furthermore, to

all appearances at least, a variety of finishes can be produced with a stone of a given grit. The hone is simultaneously rotated and reciprocated, and it is the relationship of these two motions that determines the path of a given point of any one stick.

In usual honing practice the peripheral speed of the hone is from four to six times the reciprocating speed. The correct relationship between these motions takes into account numerous factors, including grain or fiber structure of the material honed, its hardness, the diameter and length of the work bore, and characteristics of the abrasives used. The average operating speeds for honing are approximately 200 fpm for rotation and 45-fpm for reciprocation and are generally used to advantage on low-alloy cast iron in particular. In bores of average size this combination generates a steep-angle helix which crosses back upon itself many times and results in a surface of diamond-shaped grids quite unlike markings produced by any other means of finishing. Many manufacturers will not accept such a finish and insist on having one of high reflective ability.

This highlighted surface is easily obtained without necessarily changing to finer grit stones, by increasing the rotative speed of the stones while maintaining the reciprocating speed constant. Two effects then result: Increasing the rotative speed causes the stones to glaze slightly and hence literally to iron out the surface; secondly, the helix angle changes from a steep to a shallow one. The surface looks much smoother, partly because it is planished, rather than ground, and partly because the inevitable grit marks cannot be easily seen when the bore is viewed, necessarily, from the end. The tool marks are there, nevertheless, and are at almost 90 deg to the direction of the ultimate run-in marks. An approach toward longitudinal tool marks is obtained with a steep-angle helix, and the planishing effect may still be obtained by means of slightly harder abrasives.

EXAMPLES OF DRAW-POLISHING

Rather recently, two manufacturers were convinced of the logic of this viewpoint, and carried the practical application to its ultimate conclusion. What they did was to draw-polish the surface with a reciprocating motion only, thus producing tool marks codirectional with the inevitable run-in marks. One example is taken from aircraft-engine practice. Rings were showing excessive wear after a 40-hr run-in, although the second set lasted 200 hr after the walls had been "broken in." Draw-polishing with cast-iron laps impregnated with abrasive dust stepped up the ring life to 200 hr on the initial run. The cylinder walls look the same at the start of the run as at the end. This type of lap, of course, can only be used with a steel barrel.

The second example comes from gun practice. The pneumatic recoil mechanism must show no appreciable "run-in" wear and must be ready for instant use even after years of idleness. Solid silver pistons are used. To insure what is practically a run-in fit at the start, a draw-polishing operation is used. In this operation, stones with extra wide faces are used. A special driving mechanism has been designed to permit the normal honing operation and the draw-polishing operation to be performed in the same setup. When the draw-polishing hone is in use, the standard rotary drive is omitted, and an indexing motion of the hone at the extremities of the stroke is used. The resulting surface produced is practically identical to one produced by long run-in.

FINISHES FOR ENGINE CYLINDERS

At the higher engine speeds and higher compression ratios in use today, automotive engineers are experiencing trouble in preventing blow-by of gases on the explosion stroke. The problem is being attacked from many angles. It is causing concern to piston-ring manufacturers, but the ring manufacturer cannot control the type and character of bore surface against which the rings operate. At least one automobile manufacturer is making it the practice to pin the oil-control rings in place, so that when once properly run-in, they will maintain their position. Recently it has been advocated that narrow lands be used with relatively high wall pressure for the rings to insure good seating contact. Ordinarily, this would lead to rapid ring wear, but a good run-in fit at the start greatly lengthens the life. In fact, a second set of such rings operating on the worn cylinder walls gives much better oil control and less blow-by than a similar set of rings on a reground bore that has been ground according to the older method.

Ring flutter and blow-by are a result not so much of surface characteristics as of geometric shape of the bore. In practice, there is no such thing as a perfect circle, nor a perfectly round, straight bore. It is a question of how far one can go in setting the limits of accuracy. With properly selected honing equipment, operating on properly prepared surfaces, these limits on out-of-roundness and taper may be held commercially within a few "tenths." The normal sequence of cylinder operations used to be, and still is in many plants, rough bore, finish bore, ream, and hone. Rather recently, a single-point boring tool, either a diamond or tungsten carbide, running at a high surface speed and fine feed, has replaced the reaming operation and has resulted in a bore of much greater accuracy than heretofore obtained. Productively, honing is fundamentally a finishing operation, and the hone should not be called upon to clean up major inaccuracies of the bore without allowance for consequent increase in honing costs. A well-designed hone should be self-correcting, but there remains the question of whether it is cheaper to remove metal by cutting or by abrasion.

When preceded by a single-point boring operation, the honing time can be cut to minimum. One large producer is actually cleaning up the bore in six passes of the hone. Furthermore, this particular manufacturer is using a 400-grit stone and getting better oil control than when finishing the bores of the previous model with a 500-grit stone.

Danger of seizure is greatly increased in instances where surfaces are too finely finished. The example of the gage blocks bears out this point. The nearer a so-called optical flat is approached, the nearer the surfaces come to having true molecular contact and subsequent seizure. We had a very vivid and expensive example of this action in our own shop a few years ago. A section of tubing about 18 in. in diameter had to be finished to a high polish within exacting limits. The customer supplied us with a plug gage that had a lapped finish. When we tried to gage for size, the tube was exactly on size, but we could not get the gage out with any amount of coaxing. Finally it was driven out, but the bore was ruined. The score marks were too deep to be removed without further enlargement of the bore. It seems logical to believe that had the bore been rougher, a few of the high points would have been sheared off without necessarily scoring the wall beyond repair.

The same reasoning can be applied to automotive cylinder bores. When an engine is started cold, the piston head quickly absorbs the heat of combustion and expands, more rapidly relatively than its difference in coefficient of expansion would indicate. It takes the block itself several minutes to come up to the operating temperature. Yet at this critical time, when operating clearances are reduced to a minimum, lubrication is least, for this is an example in which lubrication depends upon motion for its sustenance. More wear takes place in the first five minutes than in the next five hours. It is in such a situa-

tion that the "visually rougher" but "characteristic" surface shows to advantage.

As previously mentioned, the combination of rotary and reciprocating motion produces tool or stone marks forming a grid of diamond-shaped areas. At each corner of the diamond, a tiny pocket is formed by the intersection of two lines, and these pockets tend to anchor the lubricant film and to prevent its sheet movement. It is impossible for piston rings to scrape such a surface absolutely dry, just as a squeegee rubber cannot wipe a piece of frosted glass dry of liquid, yet it will, on the other hand, wipe a piece of plate glass dry!

CORRELATION OF FIT, RUN-IN, AND LUBRICATION

In general, three factors must be correlated when the question of finish is under consideration; fit, run-in, and lubrication. For example, if the tolerances of the final finishing operations on mating parts will not permit a satisfactory operating clearance, a planished surface on both parts should not be used. Not only is the period of running-in unduly prolonged, but the danger of seizure is imminent. The reason the old-type hand-scraped connecting-rod bearings could be set extremely tight and yet not seize was because of the hills and valleys, or lubricant pockets, left by the curved scraping tool.

The characteristic of wear of a material also is always influenced by the amount of work performed; that is, the force applied and the distance traveled. The working pressure between parts can usually be controlled, and variations in material specifications can be modified to suit.

Compared with contiguous operating parts, the part having the better wear resistance should be the more highly and precisely finished. Obviously, should the part having the greater wear resistance be more poorly finished, it would produce rapid wear on its complementary part. It does not follow, however, that the harder the material, the finer its quality of finish should be. Some alloy steels, although somewhat soft as measured in hardness numbers, nevertheless have infinitely greater re-resistance to wear than do comparatively harder materials. To carry the analogy further, soft rubber, in the presence of water, has tremendous wear resistance.

The finish of the part having the lesser wear resistance should have a nap-like or "satiny" finish (usually of a white silver color in cast iron) commensurate with the amount of wearing-in required to secure the fit desired. Soft-bonded abrasives produce the more satin-like finish because the dull abrasive particles break away more readily, thereby presenting fresh, sharp cutting grains to the work. Abrasives with harder bonds tend to glaze, and as a consequence, planish the work surface to a close-grained structure. Abrasives with very hard bond cut slowly unless the work surface is interrupted by ports, which act as dressers for dislodging the dull abrasive particles.

Supplementary factors, such as speeds, feeds, and precision, also affect the action of the stones. When an abrasive is operating at or near the critical breakdown point of the bond, for example, an increase in the rotative speed or a decrease in the speed of reciprocation will cause the stones to glaze. A decrease in rotary speed or an increase in the reciprocating speed will counteract this tendency. It is obviously imperative, therefore, that correct relative speeds be maintained for optimum results.

CONCLUSION

In conclusion, the three important points that this paper has attempted to advocate are:

(1) Making as an objective the obtainment of affinitive surfaces possessing more nearly "run-in" characteristics, rather than absolute smoothness
(2) The importance of diametric precision relating to operating tolerances, and
(3) The consequent danger of having too smoothly finished surfaces when operated with insufficient running clearances.

Recognition of these principles should change our viewpoint as to the engineering ideal in surface finishes.

F. S. Lincoln

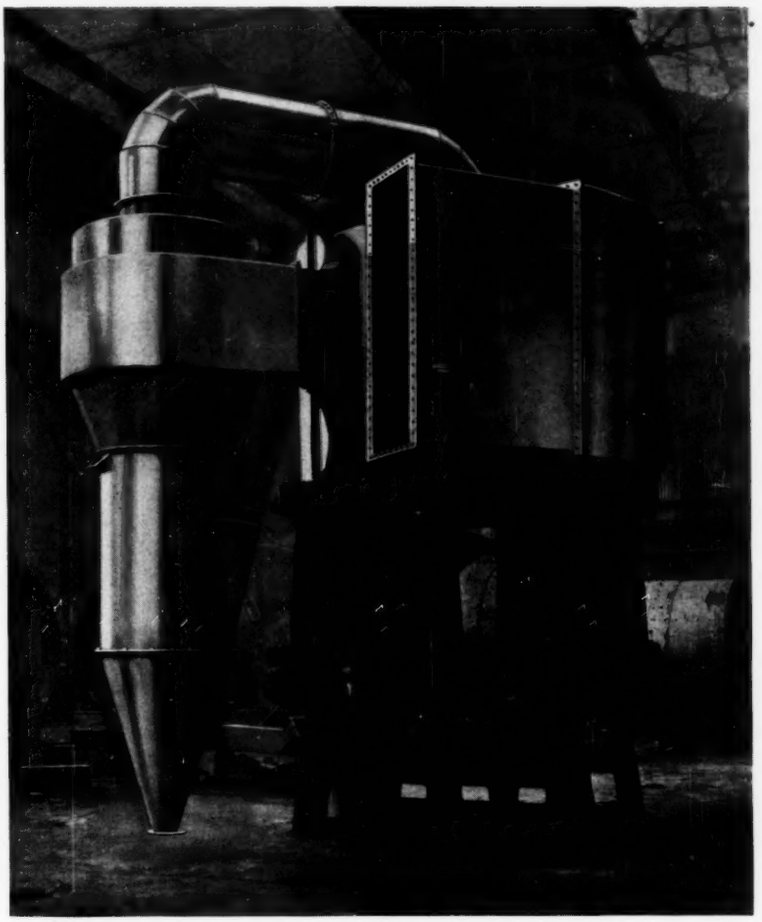


FIG. 1 CHIMNEY-TYPE DUST COLLECTOR

(The primary concentrator is on the right with the intake for the dust-laden gas visible in front; to the left is the cyclone collector, while between is the scoop connection which transfers the dust from the concentrator to the collector.)

A MODERN DUST COLLECTOR

A Study of the Principles Governing Its Design and Operation

By HERMAN VAN TONGEREN

HEEMSTEDE, HOLLAND

THE extraction of dust from its entraining gas may be accomplished in many ways. The methods more generally adopted may be grouped under the two headings, wet separation and dry separation. With either method a surprising variety of types of apparatus is available, and it is often difficult to decide which type is the most suitable in any particular case. For this reason the following discussion has been confined to a description of theory and practical experimentation which has resulted in the addition to the field of dry separation of a collector employing features of unique yet simple design which in operation give collection efficiencies worthy of earnest consideration by engineers faced with the problem of dust extraction.

Until the postwar era, most collectors were constructed by rule of thumb rather than by a careful analysis of all the relevant factors beforehand. It is true that occasionally the proper combinations were arrived at, but if not, alterations were made which produced results more or less satisfactory. In general, however, such collectors were makeshifts and very inefficient.

Modern industrial conditions and the ever-increasing attention which is being directed toward the elimination of factors contributing to air pollution demanded something better than a haphazard assembly of metal plates to rule-of-thumb dimensions. A dust collector, to be economic and efficient, must be the product of soundly applied aerodynamic principles and a thorough knowledge of the physical and chemical characteristics of the dust which is to be collected. While 100 per cent total collection efficiency is the aim of every designer, it has to be realized that this ideal can only be closely approached by a collector of special design, with a high first cost. Eco-

Contributed by the Process Industries Division and presented at the Annual Meeting, New York, N. Y., Dec. 2–6, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

tion that the "visually rougher" but "characteristic" surface shows to advantage.

As previously mentioned, the combination of rotary and reciprocating motion produces tool or stone marks forming a grid of diamond-shaped areas. At each corner of the diamond, a tiny pocket is formed by the intersection of two lines, and these pockets tend to anchor the lubricant film and to prevent its sheet movement. It is impossible for piston rings to scrape such a surface absolutely dry, just as a squeegee rubber cannot wipe a piece of frosted glass dry of liquid, yet it will, on the other hand, wipe a piece of plate glass dry!

CORRELATION OF FIT, RUN-IN, AND LUBRICATION

In general, three factors must be correlated when the question of finish is under consideration; fit, run-in, and lubrication. For example, if the tolerances of the final finishing operations on mating parts will not permit a satisfactory operating clearance, a planished surface on both parts should not be used. Not only is the period of running-in unduly prolonged, but the danger of seizure is imminent. The reason the old-type hand-scraped connecting-rod bearings could be set extremely tight and yet not seize was because of the hills and valleys, or lubricant pockets, left by the curved scraping tool.

The characteristic of wear of a material also is always influenced by the amount of work performed; that is, the force applied and the distance traveled. The working pressure between parts can usually be controlled, and variations in material specifications can be modified to suit.

Compared with contiguous operating parts, the part having the better wear resistance should be the more highly and precisely finished. Obviously, should the part having the greater wear resistance be more poorly finished, it would produce rapid wear on its complementary part. It does not follow, however, that the harder the material, the finer its quality of finish should be. Some alloy steels, although somewhat soft as measured in hardness numbers, nevertheless have infinitely greater resistance to wear than do comparatively harder materials. To carry the analogy further, soft rubber, in the presence of water, has tremendous wear resistance.

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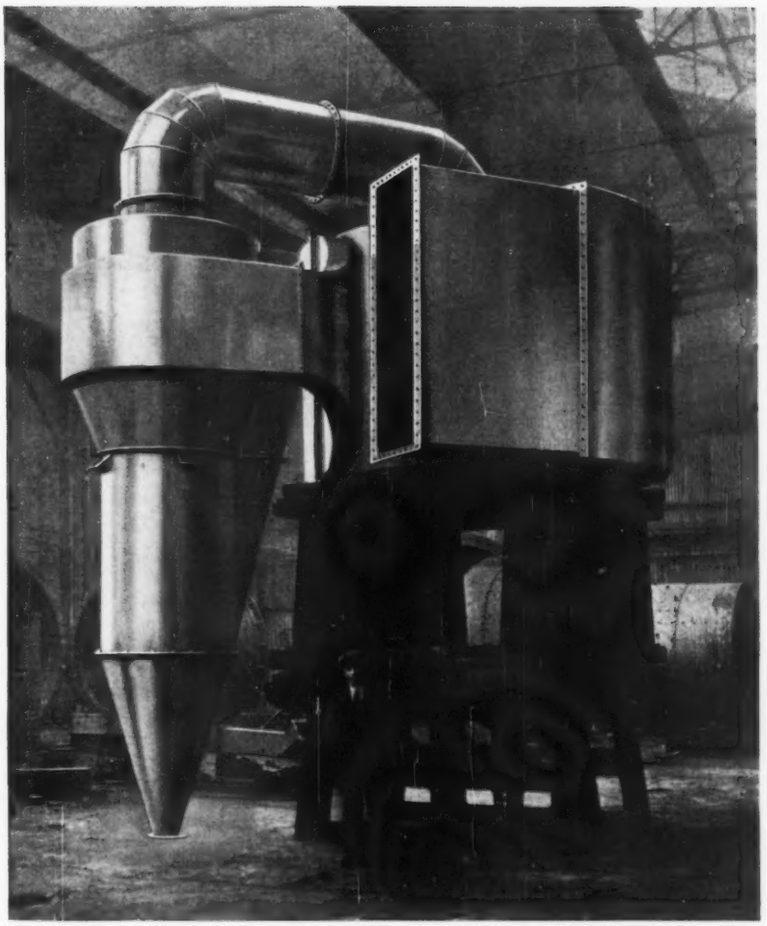

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nomics, a governing factor of desires, necessitates that the ideal standard of efficiency be based on a standard other than "total overall collection."

In the case of a dust collector for removing dust from the combustion gases of a steam generator, the nuisance factor is considered, and the design and merit of the collector are determined by its ability to remove as nearly as possible 100 per cent of the particle sizes which come within the range of the nuisance factor.

It will be appreciated that the minimum size of particle coming within this range will vary according to the location of the plant and the activity of the authorities whose duty it is to guard against pollution of the atmosphere. Within city limits particles of 30 microns, and those ranging above this size, can be taken as constituting the nuisance factor. Particles below 30 microns come within the range of natural atmospheric dust and therefore need not be considered, as in the total they represent only a very small fraction of the total dust in natural circulation.

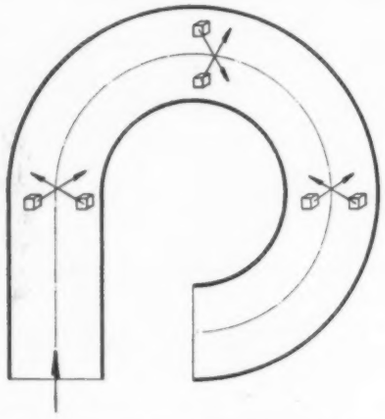


FIG. 2 SEPARATION CURVE OF A CENTRIFUGAL DUST COLLECTOR SHOWING DIAGRAMMATICALLY THE EFFECT OF TURBULENCE

With a knowledge of the problem before us, we will now turn to the investigation which preceded the building of a dust collector of improved design.

TWO TYPES OF COLLECTORS

The collectors are of two different types, namely a compound, or so-called "chimney" type, and the cyclone type. The first mentioned comprises a primary collector or concentrator coupled to a secondary or cyclone collector, while the latter type covers a single or multiple installation of cyclones handling the dust-laden gas directly without primary concentrators.

Fig. 1 shows a chimney-type collector. At the right the primary concentrator can be seen, with the intake for the dust-laden gas clearly visible in front. To the left of the primary concentrator is the cyclone collector, while between them can be seen the scoop connection which transfers the dust from the concentrator to the collector. The pipe at the top returns that portion of gas (cleaned) which enters the cyclone collector with the dust from the concentrator. Although the connection cannot be seen in the photograph, it is made to the center of the primary concentrator, this being the main discharge for the cleaned gas to atmosphere. The flange connection for attachment to the stack duct is at the bottom of the concentrator.

As previously stated, collectors of the cyclone type consist of one or more cyclones similar to that shown on the left-hand side of the photograph.

CHIMNEY-TYPE COLLECTOR AND THE EFFECT OF THE DOUBLE-EDDY CURRENT ON DESIGN

The theory usually employed in the design of centrifugal dust collectors is based on the assumption that the dust to be removed is entrained in parallel-line flow; that is, that the dust particles and entraining gas flow parallel to the walls of the collector-case bend. This theory does not hold good in practice, as the gas velocities in a centrifugal dust collector always lie above the critical velocity which lies between parallel and turbulent flow.

Turbulence is not the only factor to be considered. One which is more detrimental to good collection, unless harnessed in the proper manner, is the so-called "double-eddy current." This factor, combined with turbulence, explains why, even after the longest path of separation, all dust particles are not concentrated on the periphery of the curvature covered by the flow. Turbulence, while having some effect on the separating action, is not so detrimental to good collection because the coarse particles of dust under centrifugal force have sufficient energy imparted to them to overcome the disturbing action caused by turbulence. Thus, after a certain length of the curvature has been passed by the flow, a condition results whereby all particles capable of overcoming the turbulence by reason of their mass are concentrated on the periphery of the separation curve, while the remainder are retained in the zone of turbulence. The dust concentration is in parallel layers, greatest at the outer periphery and gradually reducing toward the center.

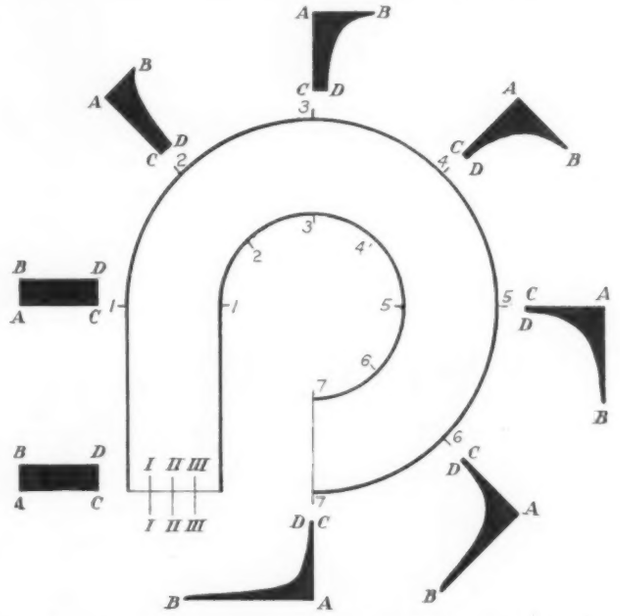


FIG. 3 SEPARATION CURVE OF A CENTRIFUGAL DUST COLLECTOR SHOWING THE SHAPE OF THE DUST CONCENTRATION AS IT BUILDS UP ON THE PERIPHERY THROUGH THE CENTRIFUGAL ACTION

It should, however, be clearly understood that this condition is only obtained when the double-eddy current is eliminated from consideration. The point at which this condition is reached is determined by:

(1) The length of the separation curve.
(2) The maximum divergent path of the dust particle.
(3) The mean radius of the separation curve.
(4) The viscosity of the entraining gas.
(5) The dust characteristics (specific weight and shape of particle).

FIG. 5 DIAGRAMMATIC ARRANGEMENT OF DUST-SETTLING DUCT—SHOWING THEORETICAL AND ACTUAL LINES OF SETTLEMENT

With normal conditions, it is possible to determine the equilibrium point fairly accurately.

Fig. 2 represents the separation curve of the normal centrifugal dust collector. The small cubes represent diagrammatically gas volumes with entrained dust, and show the effect of turbulence whereby the position of these cubes is changed from side to side by the turbulent flow of the gas stream.

Fig. 3 shows how the dust concentration builds up on the periphery through the centrifugal action, taking into account only one disturbing influence, i.e., turbulence. It will be seen that the dust concentration is uniform over the cross section of the intake and gradually becomes more pronounced in the

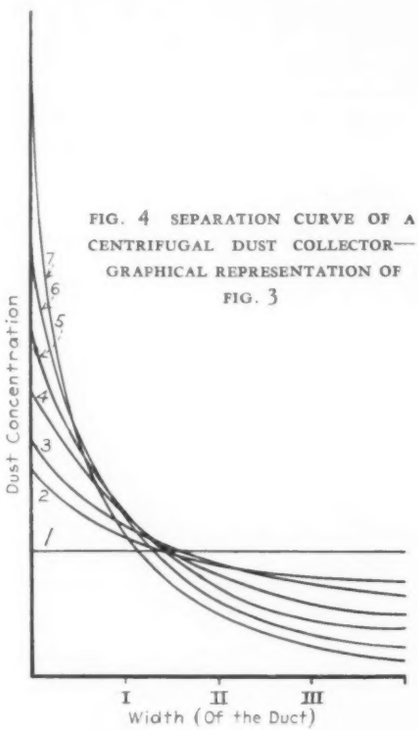


FIG. 4 SEPARATION CURVE OF A CENTRIFUGAL DUST COLLECTOR—GRAPHICAL REPRESENTATION OF FIG. 3

concentration at the periphery as the greater length of the separation curve is traversed by the gas and entrained dust, increasing from *A–B* at the intake to *A–B* at the end of the curvature. At the same time it will be seen that the concentration on the inside curve decreases from *C–D* at the intake to *C–D* at the end of the separation curve.

Fig. 4 is a graphical representation of Fig. 3.

Fig. 5 represents a dust-settling duct in which the length is many times the cross-section dimension of the duct. At one end the gas with entrained dust is blown in, and for the settlement of the particles the assumption is made that all particles have to move from the top to the bottom of the duct. Line 1 indicates the theoretical path covered before the dust particles reach the bottom. Line 2 is the actual length of the duct which has to be traversed before complete settlement of the dust.

The separating action in the centrifugal dust collector may be illustrated assuming that Fig. 5 represents a separation curve, straightened out, through which gas and entrained dust are passing. For this comparison the duct bottom, as drawn, is taken as the outer periphery of the separation curve, in which case lines 1 and 2 indicate, respectively, the theoretical and actual paths of the particle in reaching the periphery of the separation curve, while 3 indicates the influence of the double-eddy current upon the particles of small mass.

The next important step in the development of the collector was a detailed study of the double-eddy current which exists whenever a stream of gas or air flows along a curved path.

When considering the double-eddy current, it must be understood that its effect on the dust concentration is simultaneous with that of turbulence. By reason of this the concentration of the dust in parallel layers is partially destroyed by the secondary flows set up by the double-eddy current. The secondary flow builds up in definite zones heavy concentrations of dust in ring formation in which the dust is no longer carried in free suspension, but moves in heavy concentration through a circulation path governed by the double-eddy current. The progress of the dust particle through the primary concentrator is influenced by the impressed force which it receives from centrifugal action, the turbulent movement of the gas flow, and the double-eddy current.

While affected by the forces already mentioned, all dust particles tend to follow the flow of the entraining gas and only deviate therefrom by reason of their higher specific gravity. Because of this a state of equilibrium is reached by the dust particles when the centrifugal force and frictional resistance balance. Calculations for this are made according to Stokes's law.

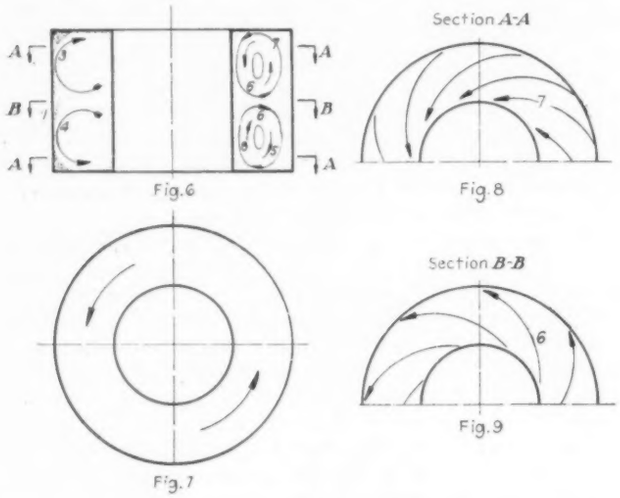
An important feature of the double-eddy current, which hitherto has not been taken into account in the design of dust collectors, is that the velocity of the fine particles of dust derived from the component of the double-eddy current is many times greater than the velocity impressed upon them by the centrifugal force. It will be shown in the following how dust losses arise which can be avoided or limited by special design features which take into account the effect of the double-eddy current and thereby make it possible to obtain a good collection efficiency.

The double-eddy current can best be described by reference to the diagrams, Figs. 6 to 9, inclusive. The main flow which produces the double-eddy current is indicated by the direction arrows in Fig. 7, while arrows 3 and 4 in Fig. 6 indicate the direction in the vertical plane. In the right half section of Fig. 6 are shown the stream lines of the current as they adapt themselves to the cross section of the circulation duct. From a study of Fig. 6, left half section, it will be apparent that the particles of dust undergoing separation from the entraining gas will be assisted by the action of the double-eddy current at the center of the duct, as the separating force at this point is that of the centrifugal force imparted to the dust particles by the sweeping gas plus the additional energy derived from the action of the double-eddy current.

On the other hand, at the top and bottom of the collector the gas flows in the opposite direction to the line of flow impressed

on the dust particles by the centrifugal action. Therefore, if the separating action is to be maintained, the dust must overcome the negative action of the counterflow in order to reach the point of desired maximum concentration at the periphery of the separation curve.

Because of the strength of the double-eddy current, it is only the coarse particles which succeed in breaking through the stream of opposite flow, and then only in part, as the bulk of



FIGS. 6, 7, 8, AND 9 DOUBLE-EDDY CURRENT DIAGRAMS SHOWING FLOW AS RELATED TO THE SEPARATION CURVE OF A CENTRIFUGAL DUST COLLECTOR

the dust is carried back to the inner curved surface because its original impressed force is reduced to zero in trying to overcome the counterflow of the gas. This explains why, irrespective of the length used for the separation curve, particles of dust can always be found on the inner curved surface in spite of the fact that calculations would lead one to expect the opposite.

The actual flow of dust and gas, at the top, bottom, and mid-section, through the planes *A–A* and *B–B* of Fig. 6, is shown in Figs. 8 and 9. In Fig. 8 the arrows indicate the direction of flow at the top and bottom, while Fig. 9 indicates the flow at mid-section. As previously stated, the coarse particles are able to overcome the turbulence and thereby reach the periphery of the separation curve, where normally one would expect them to travel around the separation curve at a fixed point above the bottom of the duct. But this is not so, as the influence of the double-eddy current forces the dust concentration at the periphery to move around the separation curve in a spiral formation.

With a knowledge of the zones in which the dust concentration in the collector takes place, the next step was the design of a suitable scoop to remove the dust from the primary concentrator to the secondary collector. The first scoop used was U-shaped, the short legs of the U being arranged at the top and bottom of the separation curve. To simplify construction the legs of the scoop were removed and a rectangular opening was used. It was found from many experiments that the change to the simpler construction did not affect the efficiency to any great extent, and therefore all recent installations have been made with the rectangular scoop construction.

In the collector under consideration, Fig. 1 and Fig. 10, the dust-laden gas is introduced into the primary concentrator at the region where the dust is concentrated on the periphery in the manner previously indicated in plan view. The heavy concentration is removed by the scoop, together with a small percentage of the total gas quantity, and passed to the cyclone collector for final purification. The amount of gas taken from the main flow may be between 8 and 15 per cent, according

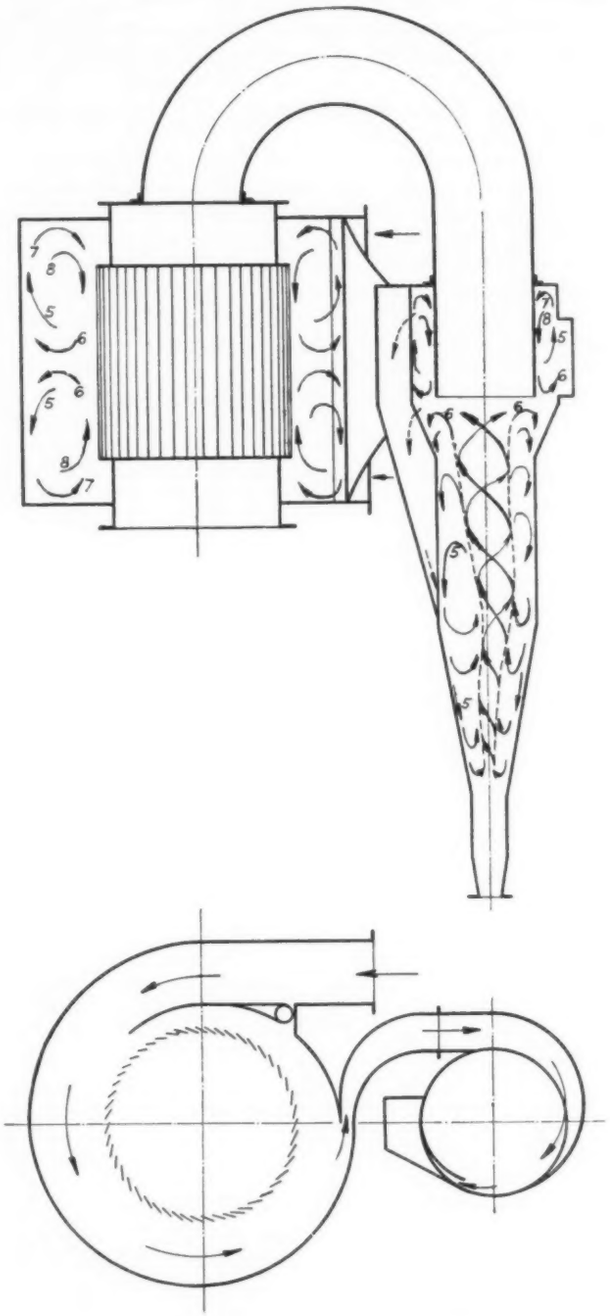


FIG. 10 CHIMNEY-TYPE COLLECTOR

(Cross section showing the flow of the double-eddy currents. The numerals 5, 6, 7, and 8 correspond to the flow shown diagrammatically in Figs. 6, 7, 8, and 9.)

to circumstances. The remainder of the gas from the concentrator, freed from the heavy dust, is then passed through vanes which are arranged about the entrance to the central discharge duct. These vanes give a further and final separation, because of the fact that they are sloped away from the direction of the gas flow inside the primary concentrator, thus obliging the

air or gas to make a turn to discharge through an angle less than 90 deg. Their separating effect is based upon the law of conservation of linear momentum.

Dust particles, which, by means of their small mass, as well as larger particles (brought in under the influence of the double-eddy current), are brought to the point at which the gas escapes from the primary concentrator to atmosphere via the central vaned discharge duct. These particles and the entraining gas travel around at a high velocity in a path adjacent to the vanes. Before any such particles can escape to atmosphere their accumulated kinetic energy must be reduced so that they can make the abrupt turn necessary to pass between the vanes, by means of which a final separation or scouring of the air is obtained; and while some of the smallest of the particles outside the collection range of the concentrator escape to atmosphere, the bulk of the dust is returned for recirculation.

As previously stated, a heavy concentration of dust occurs in the corners at the top and bottom of the inner curve, and it will be appreciated that if the vanes on the discharge were carried to the full height of the duct, an appreciable loss would be sustained at these two points. However, the design is arranged in such a way that the heavy concentrations in the corners referred to are brought back by the double-eddy current to the mid-section of the collector for further separating action.

In effect, the vanes are fitted in the zone of minimum dust concentration. Figs. 10 and 11 illustrate this principle.

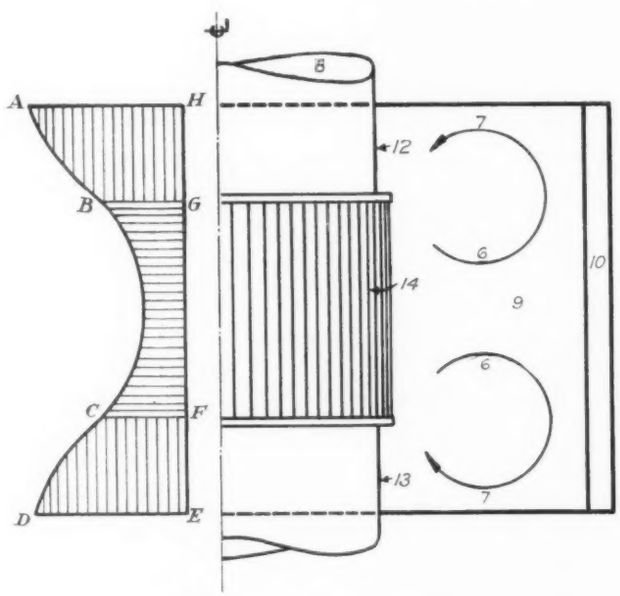


FIG. 11 CHIMNEY-TYPE COLLECTOR

(Right-hand part-section shows the position of the discharge vanes 14 relative to the flow of the double-eddy current 6, 7 while on the left-hand side of the figure is shown the shape of the dust concentration adjacent to the discharge duct. The lines bounded by the letters *AH* and *DE* indicate the maximum concentration at the top and bottom of the collector; *BG* and *CF* the minimum concentration adjacent to the discharge vanes.)

It may be mentioned here that the internal vanes, according to the design requirements, may be in a fixed position or automatically adjustable, together with the flap governing the inlet velocity to the primary concentrator.

The foregoing summarizes briefly the work which has been done to evolve a dust-collector design comprising a primary concentrator and a secondary collector.

CYCLONE AND THE EFFECT OF THE DOUBLE-EDDY CURRENT ON DESIGN

Having dealt with the primary concentrator in a compound chimney-type collector in some detail, consideration will now be given to the design of the secondary portion, or cyclone, Fig. 12, which receives the heavy concentration of dust from the primary and carries out the final separation. Here again the double-eddy current plays an influential part, and steps were taken to minimize its disturbing effect in the improved design.

Before discussing the special design features, attention will be given to the normal type of cyclone, Fig. 13, and the effect of the double-eddy current on its operation. As previously stated, this current exists whenever a stream of gas or air flows along a curved path.

In the normal type of cyclone there are two zones in which the double-eddy current functions; one in the upper cylindrical portion and the other in the lower body. Considering the upper zone first, the double-eddy current circulates between the discharge duct and the outside wall of the collector, the current being in an upward direction adjacent to the outer wall. By reason of this circulation a heavy concentration of dust builds up under the cover plate and is supported by the upward force of the double-eddy current to a point where the weight of dust under the action of gravity is sufficient to overcome the effect of the double eddy. When this point is reached, the dust accumulation suddenly falls in such mass that it momentarily overcomes the influence of the double-eddy current and a goodly portion finds exit through the gas outlet.

FIG. 12 CYCLONE COLLECTOR WITH DUST BYPASS ON LEFT

(The dotted arrows indicate the openings between the collector and the bypass.)

It will be appreciated that with this normal construction of cyclone collector the dust discharge is intermittent by reason of the fact that time is taken in building up the dust at the top of the collector to a point where its weight is sufficient to overcome the upward force of the double eddy. Numerous experiments and extensive study of the results showed that this intermittent flushing of the dust from the top lowered the collection efficiency of the cyclone more than had previously been suspected, the chief reason being that the dust passing to the discharge is always under the influence of the natural vortex, with consequent repickup.

Having determined this phenomenon, the next experiments

were directed to removing the faults and obtaining a design which would operate at higher efficiencies. From the results of these experiments it was found that the position of the gas inlet and gas outlet and the provisions of dust bypass channels all had a direct bearing on the collection efficiency. In the final design of cyclone collector all these features of design are correlated in such a way that the maximum advantage may be derived from each.

Referring to Fig. 12, it will be seen that the tangential inlet, by means of which the dust-laden gas is introduced into the cyclone, is placed at a point in the neighborhood of the meeting point of the double-eddy currents, where, as a result of their flow, an outwardly directed force is available to assist the centrifugal action in driving the dust particles to the periphery. With the gas inlet in this position a space is left at the top of the cyclone where the dust can build up to a heavy concentration without being disturbed by the incoming gas. Instead of allowing this ring of dust to fall down toward the discharge, as in normal cyclone collectors, the design under consideration is provided with a dust scoop, immediately under the cover plate, which skims off into a bypass channel dust from this accumulating ring at a rate equal to that at which it builds up. By means of the bypass channel the dust is conveyed outside the zones of disturbance, which are always present inside the cyclone, to a point where the downward flow of gas adjacent to the wall is at a maximum, at which point the dust is reintroduced into the cyclone for discharge through the bottom.

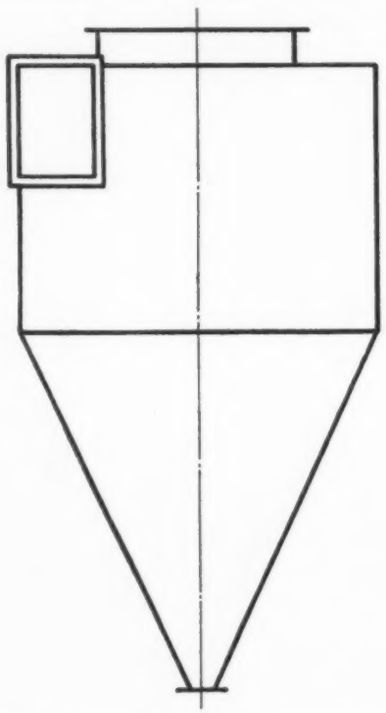


FIG. 13 NORMAL CYCLONE COLLECTOR WITHOUT DUST BYPASS

The bypass channel can rightly be described as a still-air zone, bypassing the disturbing influences within the cyclone, and its effectiveness is proved by the steady discharge of dust from the bottom of the cyclone as against the intermittent discharge from cyclones without the bypass channel.

Instead of using the bypass channel, a double-shell cyclone is sometimes employed, dust skimmed from the top being passed between the outer and inner shell to the zone of least disturbance in exactly the same way as is done with the bypass channel.

Tests carried out on cyclones with and without the bypass brought out many interesting facts. Prior to the experiments it was known that the normal type of cyclone showed higher recovery percentages when dealing with high dust concentration, and it was reasonable to expect that the cyclone with the bypass would conform to this law. However, on test it was found that this was not the case and the results of the experiments dealing with this particular point are shown in Fig. 14. The dotted line indicates the percentage of recovery obtained with the normal type of cyclone without bypass, while the full line indicates the percentage recovery when using a cyclone

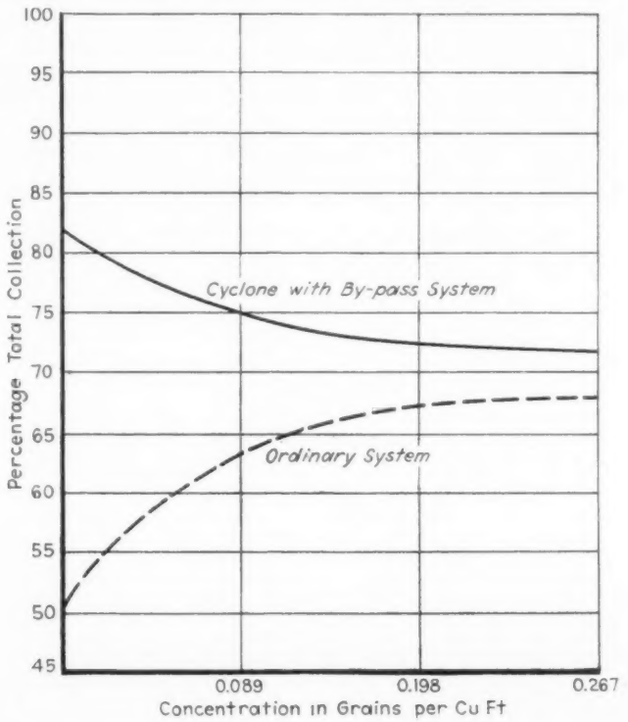


FIG. 14 GRAPH SHOWING PERCENTAGE TOTAL COLLECTION OF CYCLONES, WITH AND WITHOUT DUST BYPASS

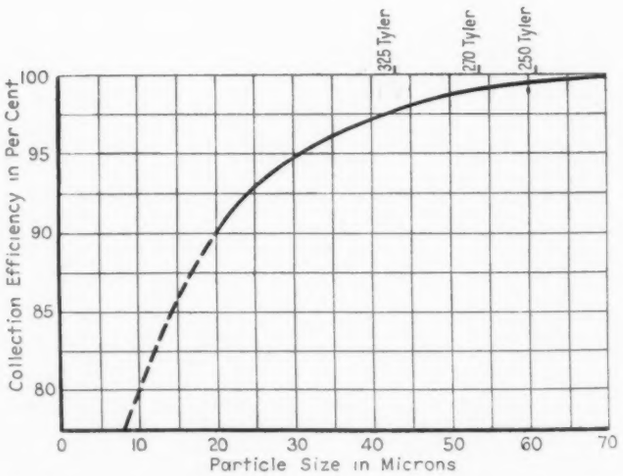


FIG. 15 GRAPH SHOWING COLLECTION EFFICIENCY OF CYCLONE WITH DUST BYPASS, AS RELATED TO PARTICLE SIZE

with bypass. From the diagram it will be seen that the collection efficiency of the cyclone with bypass drops off as the dust concentration increases, although at all times its efficiency is higher than that of the cyclone without bypass.

The dust used for the experiments was chosen especially for its fine state of subdivision, as by doing this it was possible to show up clearly the marked difference between the two cyclones.

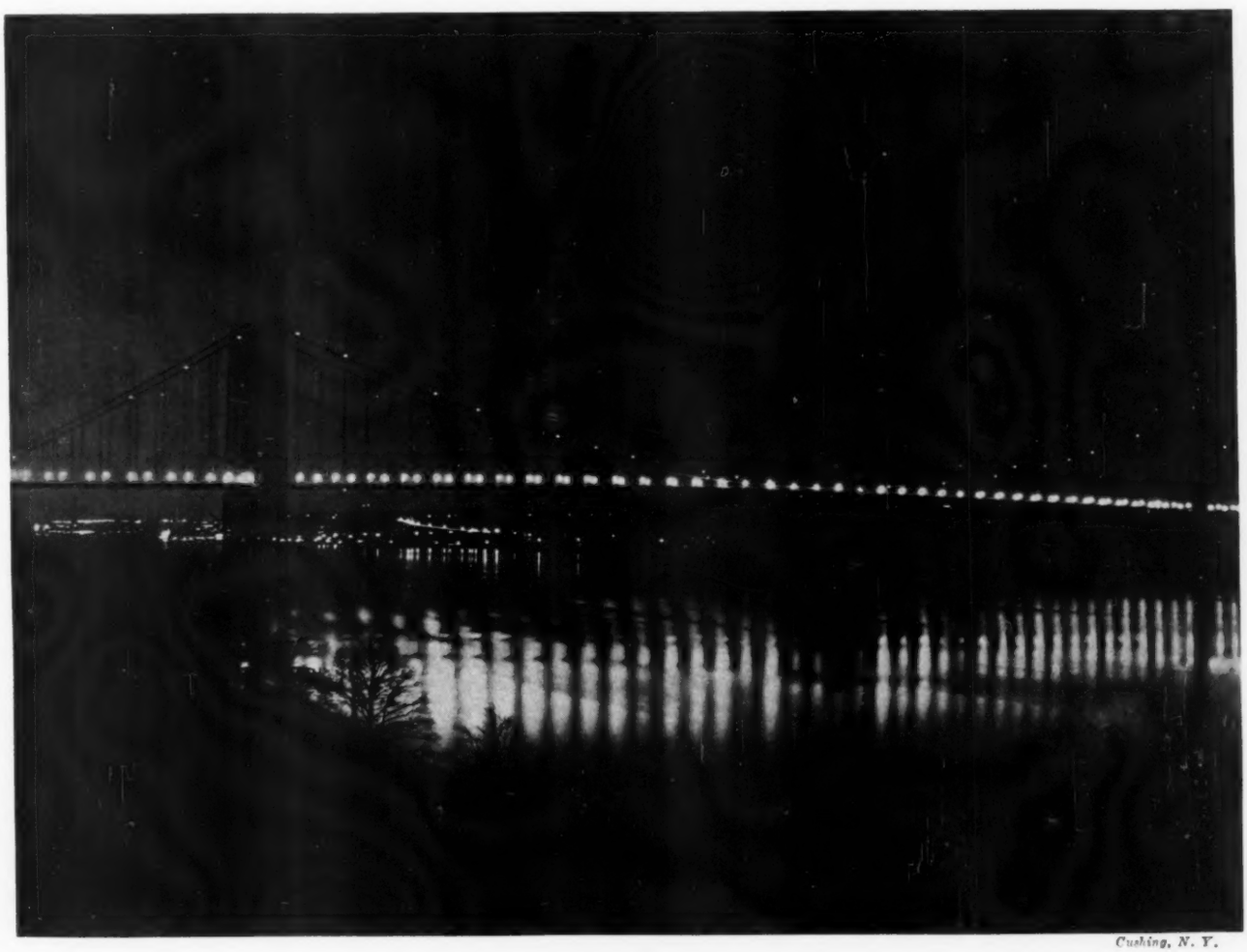
The shape of the cyclone beneath the cylindrical top has a direct bearing on the efficiency by reason of the natural vortex which is formed between the dust-discharge outlet and the cleaned-gas outlet.

If not correctly designed, cyclone collection efficiencies can be seriously reduced through the uncontrollable action of the vortex. Even with a well-designed cyclone it is still impossible to avoid picking up some dust at the tip and conveying it via the vortex spout to the cleaned-gas outlet; but it is possible to minimize this influence of the vortex by reducing the radial velocity. The reduction of the radial velocity is accomplished by extending the bottom half of the cyclone and introducing in the mid-section a cylindrical portion, the length of which is determinable by data obtained from experimentation. By this procedure the lines of flow of the double-eddy current can be extended downward so that at any point they are further removed from each other than is the case in a cyclone without this special extension. The extension gives the lower radial velocity desired, and as a consequence the cyclone illustrated in Fig. 12 would give a higher overall collection efficiency than the cyclone of Fig. 13.

Commercial interpretation of the foregoing is the accomplishment of a truly high order of dust separation in large sizes of eliminators with reasonably low pressure drops. While the pressure drop is, of course, dependent upon the density of the gas, it is interesting to give an illustration of the accomplishment in the usual case of fly-ash elimination from flue gas. Even with the large sizes handling, in a single set of one primary and one secondary, 100,000 cfm of gas, the efficiencies shown in Fig. 15 may be expected as referred to the various particle sizes, and at a pressure drop not to exceed 1.75 inches of water.

While collection efficiency is largely dependent upon the specific weight of the dust as related to the density of the carrier gas, as well as somewhat upon the shape of the particles, Fig. 15 may be considered representative of a broad variety of dust-collection requirements.

Of added interest, if the existing fan for handling the gas is found to have a slight reserve capacity, is the fact that the primary may be arranged for thoroughfare flow, with pressure drop below 0.6 inch of water (for upward of 85 per cent of the total gas flow), and a small fan may be provided for the cyclone (for less than 15 per cent of the total gas flow) and according to a pressure drop: of 1.5 inches of water therethrough. The discharge from the cyclone may efficiently be passed through the central outlet of the primary, or the outflows of primary and cyclone may otherwise be carried forth, in accordance with the convenience of laying out the duct arrangement.



Cushing, N. Y.

ROUNDED-APPROACH ORIFICES

Their Use at Low Reynolds' Numbers

By J. F. DOWNIE SMITH and SYDNEY STEELE

THE apparatus and method used in the work reported in this contribution were substantially as described in a previous paper,[1] the only major change being the substitution of static-pressure taps for the impact tubes upstream from the orifices. This was done by filling the previous holes with solder and boring centrally through it. The inside of the pipe was then smoothed off. New calibrated copper-constantan thermocouples were employed to measure the fluid temperature to one fortieth of one degree centigrade.

The fluid used, furnished by courtesy of the Swann Chemical Co., Birmingham, Ala., was a chlorinated diphenyl (known as Aroclor No. 1248) diluted to an unknown extent by the residue of oil previously used in heat-transfer work.[2] This made it necessary to determine the specific gravity and kinematic viscosity of the mixture at various temperatures. A Saybolt universal viscosimeter was used, and as a check on the accuracy of the viscosity measurements, the viscosity of pure Aroclor No. 1248 was also determined at two separate temperatures. The values so obtained fell almost exactly on the line plotted on the A.S.T.M. tentative standard viscosity-temperature chart (D 341–32T) from data furnished by Swann Research Inc., Anniston, Ala. For the temperature range employed in the investigation the properties of the oil-Aroclor mixture used are given in Table 1.

TABLE 1 FLUID PROPERTIES, OIL-AROCLOR

Temperature, F	Density, lb per sq ft	Kinematic viscosity, centistokes[a]
60	89.3	550.00
80	88.7	119.00
100	88.0	40.00
120	87.4	19.00
140	86.7	10.40
160	86.1	6.30
180	85.4	4.15

[a] Centistokes × 0.1076 = fps units (sq ft/sec).

TABLE 2 NOMENCLATURE

Symbol	Unit	Significance
c	.....	Orifice coefficient
d	ft	Diam of straight section of orifice
g	ft per sec per sec	Acceleration due to gravity
h	ft	Head of fluid flowing
r	.....	Ratio of orifice diameter to upstream diameter
Re	.....	Reynolds' number for straight section of orifice = vd/ν
v	ft per sec	Fluid velocity, straight section of orifice
ν	sq ft per sec	Kinematic viscosity

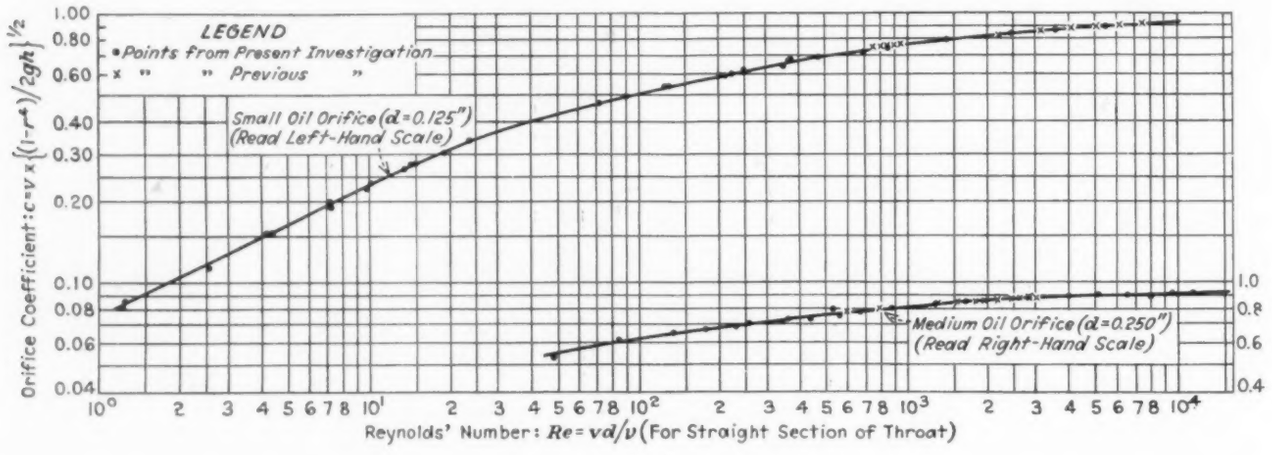

LEGEND
•Points from Present Investigation
x " " Previous "
Small Oil Orifice (d=0.125")
(Read Left-Hand Scale)
Medium Oil Orifice (d=0.250")
(Read Right-Hand Scale)
Orifice Coefficient: c=v x √(1-r⁴)/2gh
Reynolds' Number: Re=vd/ν (For Straight Section of Throat)

FIG. 1

RESULTS

The results are plotted in Fig. 1 as orifice coefficient vs. Reynolds' number for the straight section of the orifice throat. Since static pressures were used both upstream and downstream from the orifice, the coefficient c was calculated from the following equation, the nomenclature for which will be found in Table 2.

$$v = c\sqrt{\frac{2gh}{1-r^4}}$$

The curves for the two orifices cross at high Reynolds' numbers (although the separation in this region is small) and a large number of points was available, so that for the sake of clarity the curves are drawn with two separate scales of ordinates, that for the smallest orifice being on the left, that for the medium orifice on the right.

It will be seen that points previously obtained[1] fall very

(*Continued on page 780*)

[1] "Calibration of Rounded-Approach Orifices," by J. F. Downie Smith, Trans. A.S.M.E., 1934, paper RP-56-10, pp. 791–793.

[2] "Heat Transfer and Pressure Drop Data for an Oil in a Copper Tube," by J. F. Downie Smith, Trans. Am. Inst. Chem. Engr., vol. 31, 1934, pp. 83–112.

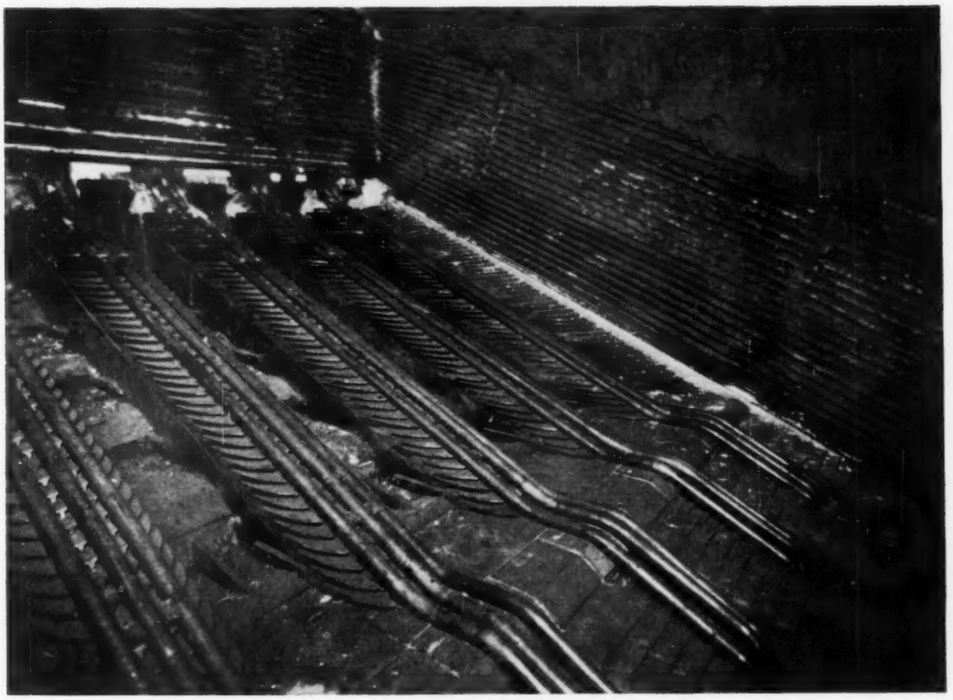


FIG. 1 PARTIAL WATER COOLING APPLIED TO EXISTING CONVENTIONAL STOKERS

Design and Development of a Water-Cooled UNDERFEED STOKER

By J. S. BENNETT AND C. J. HERBECK

USERS and manufacturers of stokers have been striving to devise some method for increasing continuity of operation. One method which has met with success has been the use of special materials, such as silicon carbide, alloy steel, and iron. A second method has involved the use of constructions to minimize air leakage below the proper combustion area and means for air cooling the iron stoker parts more effectively. This paper deals with the designs and application of water cooling to underfeed stokers.

The Cedar Rapids station of the Iowa Electric Light and Power Company is so situated that coals from western Kentucky, Illinois, and Iowa are available. This company was one of the pioneers in employing the multiple-retort underfeed stoker for burning Illinois and Iowa coals, and was among the first to utilize air preheated as high as 425 F for burning Middle Western fuels with the same coal-burning system.

The promulgation of codes under Government control affected the local fuel situation to a decided degree, making certain coals more attractive, if they could be burned successfully. It was found, however, that one coal obtained from a northern Illinois strip mine was substantially lower in price on the Btu basis, but could not be burned on existing underfeed stokers of a type designed 15 years ago when employing preheated air, because of the low fusing temperature of the ash which runs slightly in excess of 1900 F.

A typical proximate analysis of the coal on the as-fired basis is as follows: Moisture 16 per cent, volatile matter 37 per cent, fixed carbon 37 per cent, and ash 10 per cent. The sulphur, separately determined, is 3.17 per cent and the heating value is 10,436 Btu per lb as fired.

The Iowa Electric Light and Power Company, cooperating with the stoker manufacturer, studied the problem and came to the conclusion that the most effective method of handling the situation was to apply water cooling to the stoker. Waterwalls supplied with water from the boiler drum by a booster pump were in service on all four sides of the furnace. It was therefore possible to apply some of these same forced-circulation tubes to the existing stoker structure. The first step is illustrated in Fig. 1, except that water cooling was applied to the tuyère section only. Cooling the tuyère section in this manner had a pronounced effect on the behavior of the fuel. The fuel bed appeared more porous, the air ports were kept open at all times, and problems of coal distribution on the underfeed section disappeared. However, when the fuel bed reached the non-water-cooled section at the lower end of the

Contributed by the Fuels Division for presentation at the Annual Meeting, New York, N. Y., Dec. 2–6, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

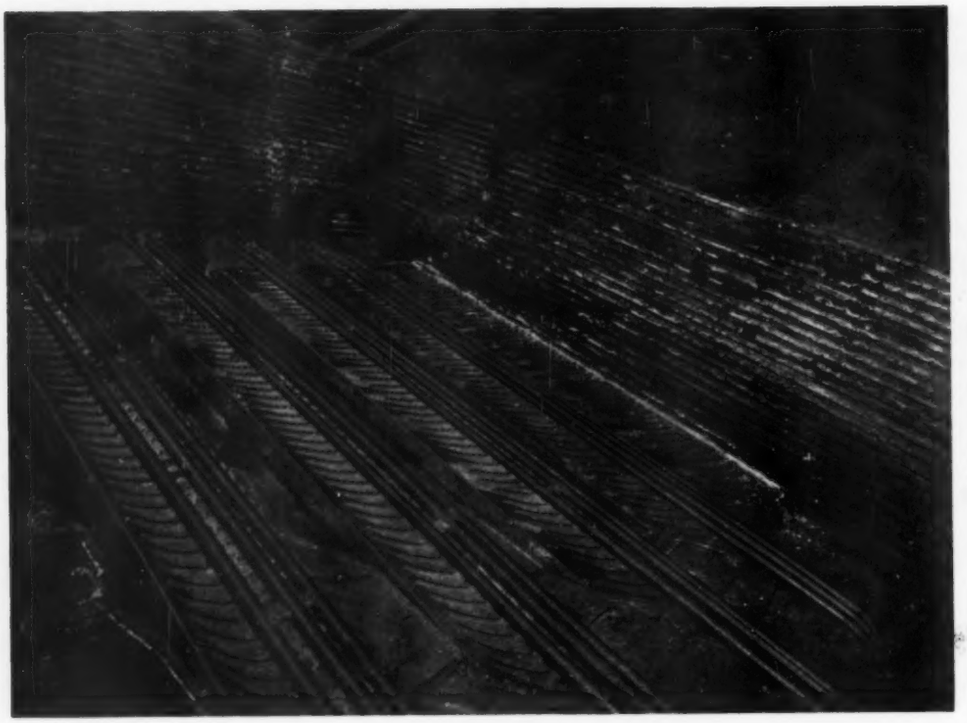


FIG. 2 STOKER SHOWN IN FIG. 1 MODIFIED TO IMPROVE FUEL DISTRIBUTION

stoker, the even flow of fuel was interrupted, which seriously impaired the operation of the unit as a whole.

The next step taken was to extend the cooling, formerly stopping at the tuyères, across the overfeed section, Fig. 1. The moving overfeed section immediately under the tubes was made stationary, but movement between the tubes was retained. This improved the situation, but difficulty was still encountered in feeding the fuel bed beyond the end of the tuyères. The elimination of the horizontal tube section by advancing the tuyère section toward the rear wall, as illustrated in Fig. 2, followed. This straightened the tubes and helped conditions materially, but was not entirely satisfactory.

At this point it was felt that it might be impracticable to solve the problem completely without rebuilding the entire stoker, and the Iowa Electric Light and Power Company arranged for the fabrication of a complete new stoker equipped with a rotary ash discharge to replace one of the existing dump-grate stokers. The ideas crystallized in designing this machine suggested the possibility of making a stationary water-cooled overfeed section. In order to make sure this was practicable, it was decided to replace the moving overfeed sections of the rebuilt dump stoker with stationary water cooling to determine the results without the moving sections. It was found that with the chilled surface provided by the stationary air-admitting section at the rear, Fig. 3, the refuse could be fed across easily and reliably. The development had reached the point where all air-admitting portions were water cooled except the half tuyères at the side, and as some slight maintenance had been encountered there, a single tube was added on each side. This left the dump plates the only section exposed to any serious degree of heat without water cooling.

The experimental stoker now operated reliably and efficiently, so seven stokers were converted as quickly as possible to embody all the features described.

At this point, it might be well to comment on features other than those of a purely mechanical nature. The high heat-transfer rates through air-swept cast iron are well known. A chart[1] presented in 1928 shows that the heat transfer through air-swept cast iron exposed to normal furnace temperatures may be as high as that obtained through waterwall tubes. These data indicate that it is virtually impossible to burn air-swept iron furnace parts provided they are bathed constantly by high-velocity air streams. The fact that furnace parts do burn is clear evidence that the air flow has been interrupted.

Consider the process of burning coal in a multiple-retort underfeed stoker. The fuel enters the trough-like retort under the front wall, moving along the retort, with a certain amount fed upward to replenish the coal consumed, the proportion of ash increasing as the fuel moves toward the discharge end. The high furnace temperature resulting from the characteristic high CO_2 produced by a machine of this type melts a portion of the ash which trickles down into the fuel bed until it reaches a zone where the temperature is sufficiently low to solidify the ash particles. Then the solid particles, with others of like nature, resume their travel toward the point of ash discharge. Where an abnormal condition is produced, the hot zone may be so close to the air ports of the stoker that molten ash will run into these apertures shutting off the air flow, and raising the temperature at that point, allowing more ash to accumulate. Normally, the accumulation of ash, after increasing sufficiently in size, is carried away by the upward and rearward movement of the green coal in the retort. Under extraordinary conditions the fused ash is not dislodged and damage to the stoker results. The obvious solution is the application of some means to maintain a reliable cold zone adjacent to the air-admitting surfaces. The results obtained with multiple-retort underfeed stokers at the Hell Gate Station of the United Electric Light and Power Company and at the Saginaw Plant of the Consumers Power Company, where the water-cooled furnaces of the type known today were first

[1] "Development and Recent Design of Stoker-Fired Equipment for Steam Generation," by Joseph G. Worker and Joseph S. Bennett, Trans. A.S.M.E., vol. 50, 1927–1928, paper FSP-50-70, Fig. 18.

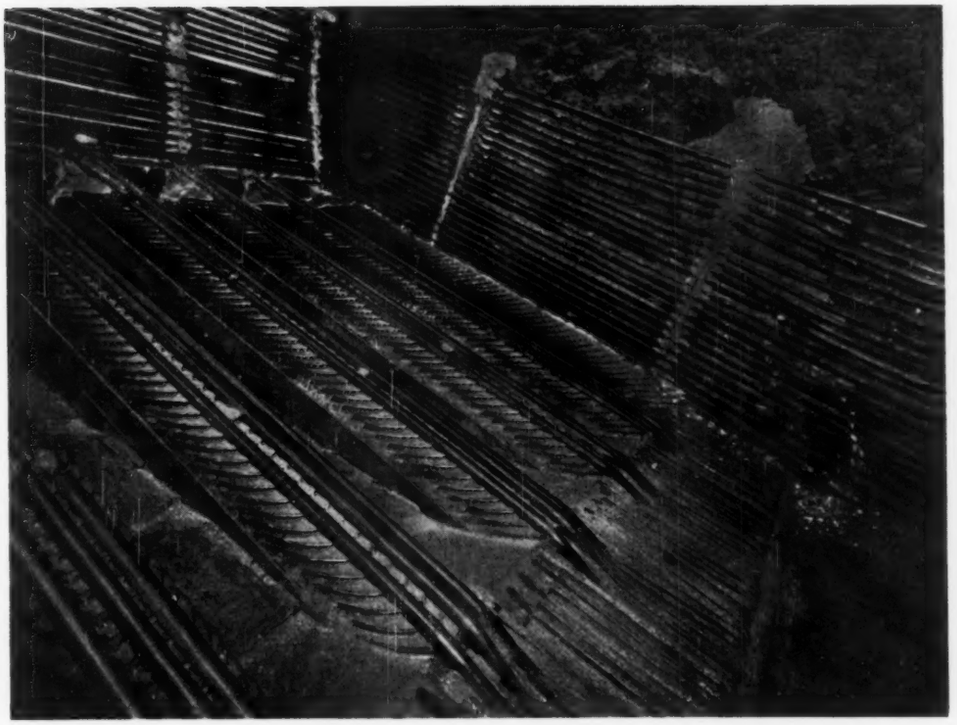


FIG. 3 STOKER WITH ALL AIR-ADMITTING SURFACES PROTECTED BY WATER COOLING

introduced, naturally led to the use of tubes as part of the boiler heating surface for stoker protection.

One effect noticed when water cooling was applied to the stoker was the reduction in the power required to drive the stoker. The fuel bed appeared to be looser and moved more freely, and fused ash did not accumulate on the underfeed section. Attention was directed to the possible harmful effect resulting from the introduction of relatively cold tubes into the fire. It is a well-known fact that stokers in northern climates operate successfully with very cold air entering the fuel bed, so it was not expected that the introduction of tubes containing water at approximately 400 F would have any harmful effect. This belief was confirmed by actual operating experience. The furnace was just as clear and free from smoke with the water-cooled stoker as it was with the air-cooled type.

The performance was further checked by burning western Kentucky coal where a definite comparison could be made with a totally different type of fuel. In both cases the combustion was affected favorably. Further attention was directed to the possible abrasive effects of the fuel traveling over the tubes, observing the overfeed section especially, where it was thought that abrasion was most likely to occur Although a number of the tubes have been in the furnace for a period of 16 months, no appreciable wear can be detected, and some show the original scale and shop marks. As a further check, the horizontal and vertical diameters of some of the tubes were measured with calipers and were compared with new tubes. No differences could be found.

Operating data were available from the burning on conventional stokers of Iowa and western Kentucky coals with the characteristics listed in Table 1, and these were compared with the results obtained when burning the northern Illinois strip-mine coal described previously.

It was found that the northern Illinois coal, which has much more troublesome characteristics, when burned on water-cooled stokers gave efficiencies equal to those found with the two other coals burned on conventional air-cooled stokers, and the reliability of the water-cooled stokers was much greater.

So far there has been no stoker furnace maintenance on the water-cooled stokers except routine inspection and cleaning. It has been found desirable to replace the distributing pushers on the old stokers by new ones to reduce air leakage into the retort. The cost of these changes and the routine inspection for a four-month period, during which 40,000 tons of coal were burned, has amounted to 1.77 cents per ton. There have been no furnace replacements in the stoker with the rotary ash discharge because of the fact that the entire air-admitting surface is water-cooled.

TABLE 1

	Iowa	Western Kentucky
Moisture, per cent	17.7	10.9
Volatile matter, per cent	30.4	33.5
Fixed carbon, per cent	34.6	43.6
Ash, per cent	17.3	12.0
Sulphur, separately determined, per cent	5.4	2.2
Btu per pound (as fired)	8988	10,584

As a further check on the reliability and efficiency of these rebuilt dump-type stokers, a 96-hour run was made with a fuel-burning rate of 52 lb per sq ft of air-admitting surface per hr. The heat-liberation rate in the furnace was 52,000 Btu per cu ft per hr.

The authors believe that a comparison of machines of similar design based on the amount of coal burned per square foot of air-admitting surface is more scientific than one based on the pounds of coal per square foot of projected grate area. The air-admitting area was determined by multiplying the stoker width by the dimension obtained when measuring down the tuyères from the front wall to the point where air admission under pressure stopped. Table 2 presents a comparison of both methods of rating the stokers.

In the meantime work had been proceeding on the fabrication

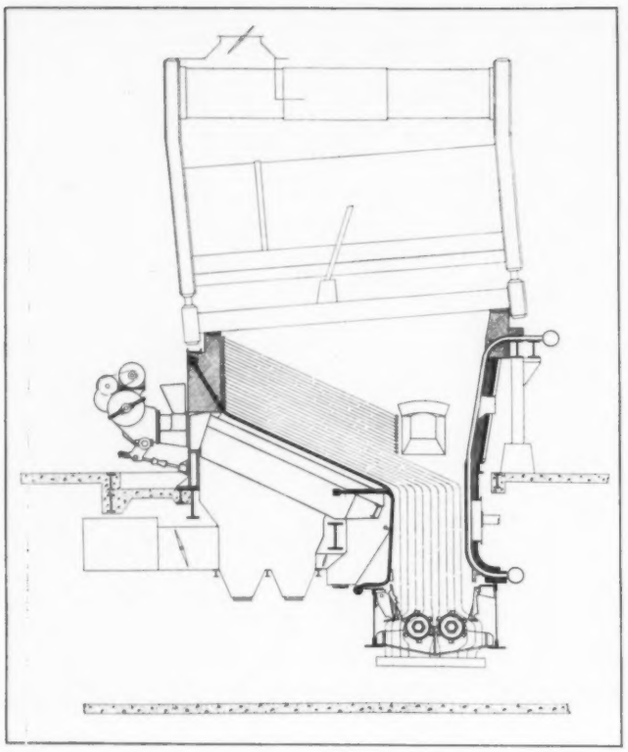


FIG. 4 WATER-COOLED ROTARY-ASH-DISCHARGE STOKER

and erection of a stoker with a rotary ash discharge developed as a result of the field experience obtained to replace one of the original eight dump-type stokers. The design and application can be understood most conveniently by reference to Fig. 4. A header at the bottom of the stoker ashpit is supplied by a downcomer from the boiler drum. The water from this header rises through the boiler tubes placed along the face of the stoker ashpit. Some of the tubes continue along the line of the tuyères into a header in the front wall, and others are carried under the bottom fuel-distributing pushers into a header placed in the windbox. The absence of the moving overfeed section, characteristic of all previous high-duty underfeed stokers, will be observed. In Figs. 5 and 6 it will be noted that tubes have been placed on three rows of tuyères and under two pushers only, permitting a view of the interior stoker structure. The original installation involved refractory construction backed up by metal behind the waterwall tubes as indicated by the white area at the lower left-hand corner of Fig. 5. Field experience later showed the desirability of continuing the metal backing, used in the upper part of the ashpit, down to the bottom of the stoker.

This unit was placed in service during May, 1935, and up to the time of writing, none of the furnace portions of the stoker has required replacement. In an effort to determine whether any weaknesses existed, large portions of the stoker were left uncovered by fuel, and a continuous run day and night for seven days was conducted with extremely low excess air and as high as 17 per cent of CO_2 at the boiler outlet. During this run, the slag ran down the walls constantly, but no operating trouble was encountered, and at the end of the run the stoker was found to be unharmed. Fuel-burning rates up to 54 lb per sq ft of air-admitting surface per hr have been maintained, with negligible combustible in the refuse and with a clear furnace and stack, an important feature, considering the fact the release rates in the furnace ran as high as 58,000 Btu per cu ft per hr with coal containing 37 per cent of volatile matter. The maximum coal-burning capacity of the unit has not been determined because of the limitations imposed by the draft and the boiler.

TABLE 2

	Projected grate area, sq ft	Air-admitting surface, sq ft	Lb per sq ft per hr Projected grate	Lb per sq ft per hr Admitting surface
Rebuilt water-cooled dump stoker	160	124	40	52
Present rotary-ash-discharge stoker	180	160	48	54
New rotary-ash-discharge stoker..	524	500	45	47

The Iowa Electric Light and Power Company, in the meantime, had made an analysis indicating the desirability of installing a 5000-kw turbine taking steam at a temperature of 750 F and a pressure of 675 lb per sq in. and exhausting it into

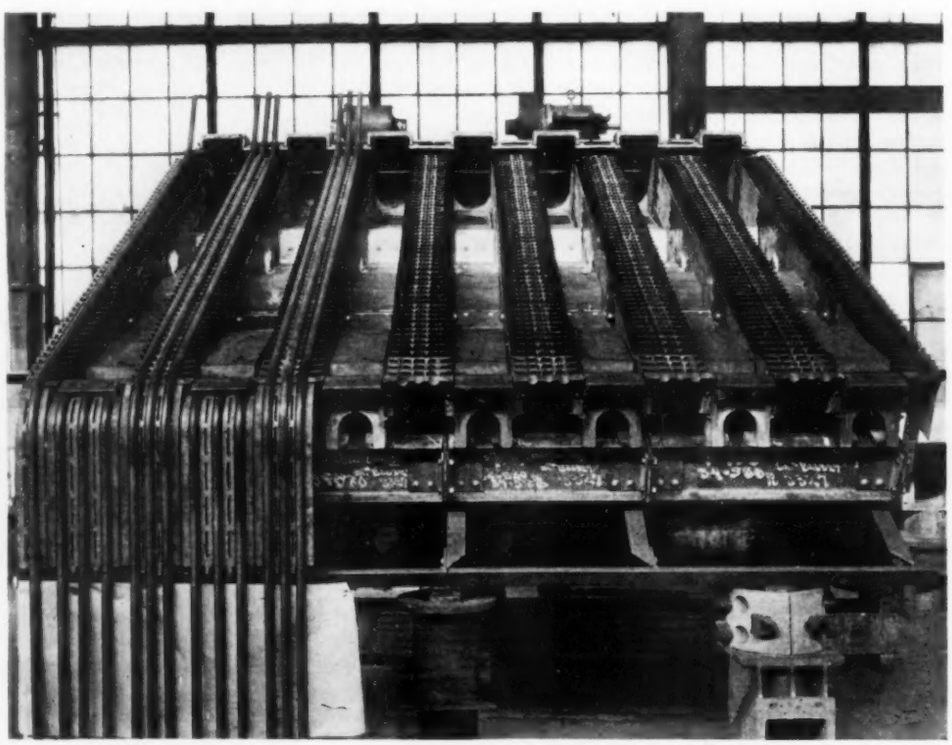


FIG. 5 SHOP PHOTOGRAPH OF THE STOKER ILLUSTRATED IN FIG. 4

existing low-pressure turbines. Building conditions were such that it was decided to replace two 500-hp boilers by one steam-generating unit with a continuous steam capacity of between 200,000 and 250,000 lb per hr. An exhaustive analysis of the best method of coal burning was made, in which factors, such as first cost, efficiency, maintenance, reliability, auxiliary power consumption, maximum possible electrical output, possible slagging of the boiler tubes, and fly-ash nuisance, were considered, and a decision was made to employ a multiple-retort water-cooled underfeed stoker with a length of 21 ft 7 in.

The steaming rate of 200,000 lb will give a fuel-burning rate of 47 lb per sq ft of air-admitting surface and a release rate in the furnace of 30,000 Btu per cu ft per hr. At 250,000 lb per hr, the release rate is 38,000 Btu per cu ft per hr. Provisions have been made for adding zoned-air control of the type described by Driscoll and Sperr,[2] should future conditions require more steam than it is contemplated to generate at the present time.

The furnace of the new unit will be completely water-cooled and air for combustion heated to 450 F will be employed. It was decided to eliminate the booster pump for cooling the new stoker unit, Fig. 7. Water from the boiler drum enters the bottom header at *A* and flows by natural circulation to headers *B* and *C*, and then it returns to the boiler drum in the same way that it would with any other waterwall. The tubes leading to the header *C* form an effective front waterwall for the furnace.

It is felt that the water-cooled stoker will have a marked effect on the design of steam plants in the future. This construction, combined with the present high mechanical reliability of the multiple-retort underfeed stoker, should do much to reduce boiler outage. Stoker water cooling should permit the use of higher air temperatures than have been employed previously. Experience indicates that the resulting loose and homogeneous condition of the fuel bed allows a more effective use of the entire grate surface and should permit somewhat higher fuel-burning rates, and may be expected to be reflected in reduced slagging of the boiler tubes and generally improved performance. It is believed that this construction, while of great value in burning Middle West fuels, may be expected to be more important along the Eastern seaboard, where coals containing a small percentage of ash with a relatively high fusing temperature can be burned with extremely high preheat.

In closing, the authors desire to express their appreciation of the assistance offered by members of their respective organizations who by their unremitting zeal have made possible these developments in so short a period of time.

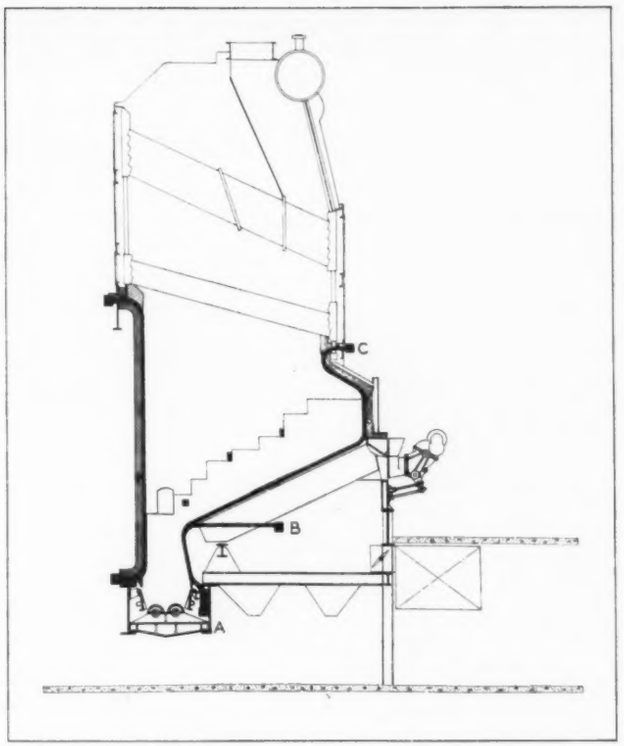


FIG. 7 COORDINATED NATURAL CIRCULATION OF WATER-COOLED STOKER AND FURNACE TO GENERATE 200,000 TO 250,000 LB OF STEAM PER HOUR

[2] "Ten Years of Stoker Development at Hudson Avenue," by John M. Driscoll and W. H. Sperr, Trans. A.S.M.E., February, 1935, paper FSP-57-3, pp. 49–58.

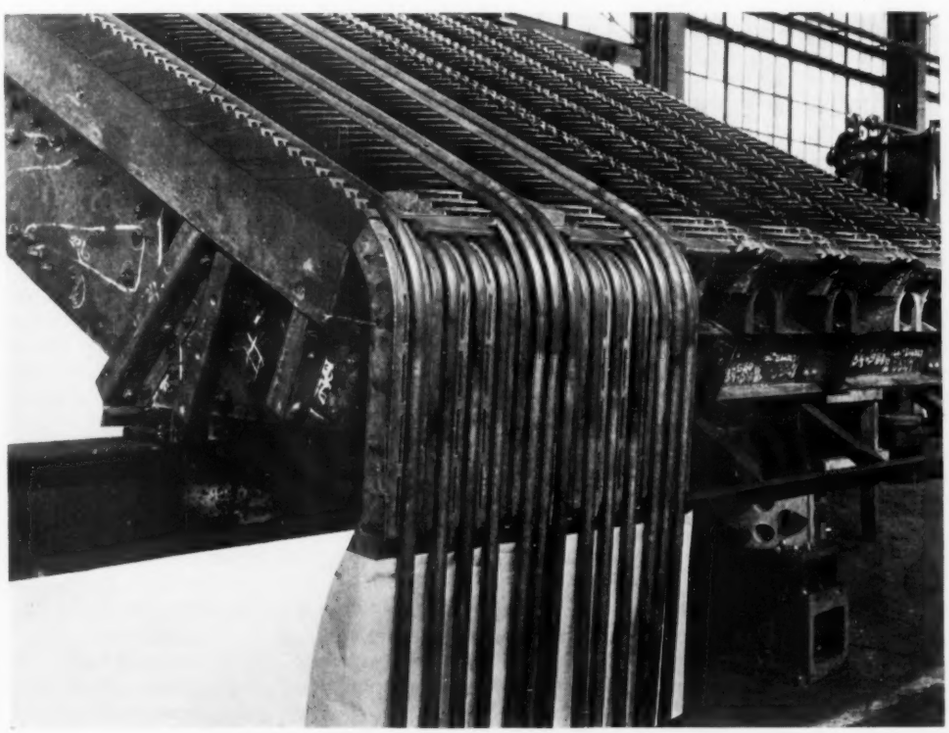


FIG. 6 THE ASHPIT SECTION OF THE STOKER ENTIRELY WATER COOLED

THE SECURITY MARKETS

By FLOYD E. ARMSTRONG

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE security markets have come to hold a place of great importance to the average investor in these days of corporation control over so much of our national wealth. For most persons the only practicable vehicle for putting their savings to work is some kind of stock or bond. Many will therefore find it distinctly to their advantage to examine with care a new book published by the Twentieth Century Fund, Inc.[1] This work represents the findings of a research staff of economists and others under the direction of Alfred L. Bernheim.

The authors have made a thorough study of the exchanges and present a comprehensive and detailed picture of their workings, together with a critical analysis of the practices that have prevailed. They give opinions as to the best ways of curbing evils which they found existing and offer suggestions for changes that would, they believe, make for more efficient functioning of the markets.

It is unfortunate that most of the manuscript for the book was prepared before the enactment of the Securities and Exchange Act of 1934, because that act is intended to correct much of what the book criticizes. This defect, if it may be so named, is in part offset by a concluding chapter analyzing this law and appraising its probable effects.

An ideal system of exchanges should perform certain specific functions as follows:

(1) Through the continuing activity of trading they should establish prices which at all times approximate the true investment value of the securities that are being bought and sold. This value will, if properly arrived at, be based on the income-yielding prospects of the various companies represented, capitalized at the rate of interest pertinent to the particular concern in the light of its risk factor.

(2) A ready market should be maintained with reasonable price continuity.

(3) Through this evaluation process, the exchanges should serve to direct the flow of the nation's capital into channels most certain to prove profitable, and thus contribute to the most economic use of that capital.

The findings of this study reveal how far we are from realizing these ideals.

That the performance of the aforementioned functions is a matter of great social significance is made apparent by statistical data, which shows that Government and corporation bonds and corporation stocks have a total face value of from $130 billion to perhaps $150 billion. It is estimated that about 64 per cent of all bonds and about 70 per cent of all stocks (in terms of their total face value) are listed on the exchanges. Figures of this sort prove that the ten million or more actual stockholders in the United States have a transcending interest in the institution in which the measure of their wealth is determined.

Space is given to consideration of the interaction existing between the security markets and our banking system. The position of American banks is shown to have been profoundly affected by the security markets, more especially because bank portfolios have, since about 1921, steadily increased their holdings of corporate securities as their commercial loans have diminished. This circumstance has made the asset items of banks much more volatile and has contributed to the disturbing results that come with great declines in security values. Blame is attached, by one of the authors, to the Federal Reserve Board for poor judgment in framing a policy of credit control before 1929, as well as for the inadequate methods used to curb what now appears to have been excessive stock speculation. The validity of this criticism against the central banking authority must rest on the larger question of whether or not it is the function of government to control or to attempt to control the use of credit, other than to see that there shall at all times be adequate credit available to meet the needs of business.

The stock-market boom that collapsed in 1929 and the succeeding period of deflation and liquidation have emphasized the dependence of our institutional investors (colleges, foundations, life and other insurance companies, and savings banks) on the security markets. Increasingly, such institutions have expanded their investments in securities and with a tendency to increase the ratio of common stocks as the upswing of the business cycle progresses. The inevitable collapse not only brings about curtailment of expansion programs, but often forces retrenchment or suspension of research and extension services in the case of colleges and foundations, while insurance companies and savings institutions have been forced to seek legal assistance to relieve them (at least temporarily) from the insistent demands of policyholders and depositors.

It has long been held by most students of business and the markets that changes in the level of security prices precede the upturns and downturns of industrial activity. Thus it has been common to refer to the security markets as barometers of business trends. This tendency of markets to "make a line" and advance or recede before business changes was explained by assuming that "insiders" liquidated or accumulated their stock holdings before the general public could know what was impending in business. The experience of 1929 seems to contradict this doctrine because the downturn in business preceded by some months the break in security prices. This is explained by the fact that there was in that market an extensive participation by an inexperienced public. The conclusion is reached that in the 1929 market, at least, the market influenced, rather than reflected, business conditions. The widespread public participation in the rising market of the 20's increased the contribution of security values to consumer purchasing power and widened the gap between security prices and earnings, as well as the spread between security and commodity prices.

Upward of one-half of the volume under review is devoted to an analysis of the organization and operation of the exchanges. It is admitted that speculation performs useful economic functions through making the market more stable than it otherwise would be, providing continuous quotations, enabling prices to discount future conditions, and, through its

(*Continued on page 782*)

[1] "The Security Markets," by the Twentieth Century Fund, Inc., New York, N. Y.

Ninth of a series of reviews of current economic publications affecting engineering, prepared by members of the Department of Economics and Social Science, Massachusetts Institute of Technology, at the request and under the sponsorship of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

A New PHOTOELASTIC MATERIAL

Properties of Marblette Compared With Those of Other Photoelastic Materials

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MARBLETTE is a transparent phenolitic material. Because it has a high stress-optical coefficient, is easy to machine and to cast into intricate shapes, and is free from initial stresses, it may replace other materials for models in the study of stresses by means of polarized light. As a result of the greater adaptability of marblette under certain circumstances, it will greatly aid in the exploration of a large number of new fields of photoelastic studies, such as stresses in composite materials, e.g., reinforced concrete; shear stresses resulting from torsion; stresses in built-up models with cemented elements; surface stresses in three-dimensional specimens by Mesnager's method; and gravitational stresses in rotating bodies by the centrifuge-polariscope method.

PHOTOELASTIC MATERIALS

In photoelastic investigation of two-dimensional stresses in a structure or machine element, the model representing the prototype to a scale must be made from a transparent isotropic material. Such a plate, if acted upon by a system of planar forces, assumes double refracting properties, and when examined in polarized light, the internal stresses become visible in the form of an interference-fringe pattern.

Many materials have been used for the models to be tested. Some of the essential properties required by an ideal material for photoelastic investigations are as follows:

1 High stress-optical coefficient
2 Facility of machining into intricate shapes
3 Linear relation of stress to strain within the limit of working stresses
4 High elastic constants
5 Perfect homogeneity (physical and optical)
6 Absence of initial stress or removal of this by annealing
7 Absence of creep while under constant stress
8 No permanent set or residual double refraction upon removal of the applied force
9 Dependence of double refraction on stress rather than on strain
10 No development of "edge stress" under aging of the finished model
11 High transparency
12 Adaptability to built-up and reinforced models
13 Low cost.

The use of glass for models was suggested by Brewster (1),[1] who in 1815 first laid the foundation of the optical method of stress analysis. Brewster's method was first applied in America to the solution of engineering problems by C. A. C. Wilson (2), in Canada (1891) and Crandal and Marston (3) in the United States (1893), then by the European pioneers such as Mesnager (4) in France (1900) and Filon (5) and Coker (6) in England (1901 and 1910).

STRESS-OPTICAL COEFFICIENT

Among the several aforementioned characteristics, a high stress-optical coefficient should be considered as the most important, especially if the determination of the principal stresses is to be made from an interference-fringe pattern. With such a material having a high coefficient the stresses in the model can be kept to very low intensities and a stress pattern may be obtained with a sufficient number of fringes for any section desired. A material with a low coefficient may be employed under certain circumstances, provided a higher stress and a larger thickness are used. A higher stress produces large creep effects and too great a thickness causes the principal stresses at a point to vary both in direction and intensity across the thickness of the plate. Such a phenomenon will render the experimental solution of the problem inaccurate.

In view of the very low stress-optical coefficient of glass and the difficulty of machining glass plates into intricate shapes investigators have preferred synthetic materials of higher optical sensitivity, in spite of the many excellent properties of glass not possessed by the others. Celluloid (xylonite, pyralin, viscoloid) was first introduced by Coker (6). Other synthetic materials of higher stress-optical coefficient came into use later, such as pollopas (7) (Germany), l'Orca (7) (France), bakelite (8) (America and England), and phenolite (9) (Japan).

The optical sensitivity of a photoelastic material to an applied force is measured by its stress-optical coefficient c, expressed in brewsters, as first suggested by Filon (5). It is determined experimentally and computed from the well-known formula by Wertheim

$$\delta = 1.752 \frac{c}{\lambda} (\sigma_1 - \sigma_2)t$$

where δ is the relative phase difference in wave lengths between the double refracted rays of light, λ the wave length in Angstroms (A) of the monochromatic light used, σ_1 and σ_2 the principal stresses in lb per sq in. at the point considered, t the thickness in inches of the plate, and 1.752 a factor of conversion from metric to British units. With c equal to 2.70 brewsters for glass and for the 5460.9 A line of mercury light, a retardation of one wave length, corresponding to one fringe interval in a glass plate one inch thick, is equivalent to an applied stress (pure tension or pure compression) of about 1150 lb per sq in. as computed from the Wertheim formula. This is called the "fringe-stress value" of glass. Approximate values for the other materials with their equivalent stress-optical coefficients and relative optical sensitivities, with glass as a basis of comparison, are given in Table 1.

[1] Numbers in parentheses refer to similarly numbered references in the bibliography at the end of the paper.

Contributed by the Applied Mechanics Division for presentation at the Annual Meeting, New York, N. Y., Dec. 2–6, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Fringe-stress patterns for phenolite and marblette under similar conditions of pure bending test are given in Fig. 1. The richness of fringes in a stress pattern for marblette as compared with bakelite is evident from Fig. 2, where two plates of equal thickness are pressed together by a uniformly distributed force on the outer edges of the plates.

MACHINABILITY

The ease with which a material can be machined into complicated outlines by sawing, drilling, milling, filing, and polishing is of practical importance in an engineering research laboratory. The various materials stand as follows in the order of ease of machining, celluloid, marblette, bakelite, phenolite, and glass.

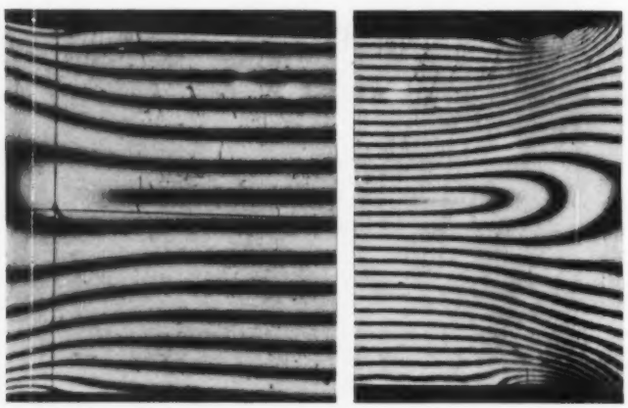

FIG. 1 FRINGE PATTERN OF STRESSES IN BEAMS UNDER PURE BENDING
(Left, phenolite; right, marblette. Test conditions same for both conditions.)

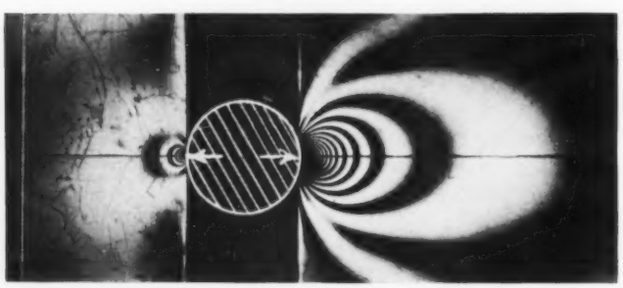

FIG. 2 FRINGE PATTERN SHOWING RELATIVE OPTICAL SENSITIVITY
(Left, bakelite; right, marblette. Test conditions same for both conditions.)

LINEAR RELATION OF STRESS TO STRAIN

A linear relation of stress to strain within the range of stresses used on the model is a condition for constant elastic coefficients. The importance of this requirement is evident from the fact that double refraction in synthetic materials is generally known to depend on both stress and strain, as will be discussed later. As a rule brittle materials are found to be lacking a strictly direct proportionality of stress to strain, if measurements are made with sensitive instruments. The same is true of celluloid and marblette, although the former is not a brittle material.

HIGH ELASTIC CONSTANTS

A high elastic limit allows the investigator to use, for a given stress-optical coefficient, higher stresses in the model in order to obtain a rich fringe pattern. Similarly, for more accurate results it is desirable to have high modulus of elasticity and Poisson's number in order to keep the longitudinal and lateral deformations of the plate under stress within their lowest possible limits. Approximate values of the elastic constants for the various photoelastic materials in tension are given in Table 2, and their stress-strain curves in Fig. 3.

TABLE 1 OPTICAL CONSTANTS

Material	Fringe-stress value, lb per sq in.	Stress-optical coef, brewsters	Optical sensitivity
Glass	1150	2.7	1.0
Celluloid	295	11.1	4.1
Pollopas	180	17.5	6.5
l'Orca	80	39.3	14.5
Bakelite	70	44.5	16.5
Phenolite	55	56.7	21.0
Marblette	23	132.5	49.3

The values assigned for marblette in Table 2 are for the manufactured plates used for industrial purposes. By a heat-treatment to make the material comparatively harder, the author has been able to obtain elastic constants for the treated marblette more than 25 per cent higher than those given in Table 2, without greatly reducing the optical sensitiveness of the material. The resistance of the heat-treated marblette to creep action, permanent set, and residual double refraction is also greatly increased. More experimentation is being carried on along this line.

TABLE 2 ELASTIC CONSTANTS

Material	Elastic limit, lb per sq in.	Max strength, lb per sq in.	Modulus of elasticity lb per sq in.	Poisson's number
Glass	..	..	9000000	4.0
Celluloid	4000	7500	350000	3.0
Bakelite	5500	14500	680000	3.6
Phenolite	7000	8500	1000000	3.7
Marblette	2750	4500	250000	2.9

It will be of interest to observe that, during the tensile tests of marblette specimens with circular fillets, considerable difficulty was encountered because of the failure that occurred in the majority of test pieces at sections in or near a circular fillet, where a high stress concentration resulting from the kind of curve adopted for the fillet is known to exist. Such types of failures are common with specimens of other synthetic materials and also in the testing of cylindrical specimens of metal in tension. As in a previous photoelastic investigation a spiral fillet was found by the author (10) to eliminate the stress concentration entirely, such a fillet was finally adopted for the test bars of marblette and proved to be satisfactory.

OPTICAL AND PHYSICAL HOMOGENEITY

Perfect optical and physical homogeneity of material throughout the entire test plate is of prime importance. During an extensive series of tension tests of bakelite made with Prof. W. J. Krefeld at the testing laboratory of Columbia University, it was found that results obtained with specimens cut from different sections of a 6 in. × 12 in. plate varied considerably in many cases. Such variation of homogeneity is expected to exist in all the other synthetic materials as well, including marblette. Hence, any number assigned to these materials as an optical or elastic constant should be regarded as an approximately average number for the material that is under consideration.

INITIAL STRESS

In a majority of cases bakelite and phenolite plates have sufficiently large initial stresses to render their use prohibitive before they are properly annealed. In many instances, especially with plates of a thickness of $^3/_8$ in. or more, the complete removal of the initial stresses by annealing is inadequate. Consequently, when a hole or a notch is cut into the finished plate, the presence of the initial stresses in the regions thus disturbed becomes more accentuated. Fortunately, marblette, even in large-size plates (12 in. × 14 in.) has been found to be practically free from the effect of initial stress and hence can be used directly.

EFFECT OF CREEP

The effect of creep, mechanical or optical, no matter of what rate and intensity, is always to introduce a certain amount of error in the final results. It is found that in nearly all materials the rate of creep depends upon the intensity of the applied force and is always larger during the first few minutes. With regard to resistance against creep action under equal stress intensities, the various materials stand as follows, glass, phenolite, bakelite, celluloid, and marblette. Glass is practically free of creep phenomenon. Extensive creep studies are available for celluloid (11), bakelite (17), and phenolite (13). Marblette, as manufactured, shows considerable creep action under moderate stresses. As heat-treated plates of this material have shown considerable improvement in resistance to the effects of creep, as well as of permanent set and residual double refraction, creep curves under various stages of constant stresses will be given in connection with further studies of the optical and physical characteristics of the heat-treated marblette.

ABSENCE OF RESIDUAL DOUBLE REFRACTION AND PERMANENT SET WHEN FORCE IS REMOVED

The complete absence of residual double refraction and permanent set upon removal of the applied force is necessary, especially in cases where the model is to be loaded and unloaded successively, as in the case of measuring the sum $(\sigma_1 + \sigma_2)$ of the principal stresses by means of a lateral extensometer. The various materials stand in the same order in respect to their resistance to residual double refraction and permanent set as in the case of creep action. Marblette, in spite of its several desirable qualities, unfortunately possesses high creep action and proportionally larger residual double refraction and permanent set, if the comparison is made for equal stresses. However, for equal fringe numbers in a pattern, the stress intensities being in inverse ratio to the optical sensitiveness of two given materials, relatively lower stresses are necessary with marblette, and hence the use of this material for models subjected to uniformly distributed loadings is possible. In the special cases of specimens subjected to concentrated loads acting upon a small area the use of a reflection type of polariscope is highly recommended. Such a polariscope produces twice the number of fringes in a stress pattern as would be obtained with an ordinary transmission polariscope; therefore, the applied load, and hence the intensity of stresses in a marblette model, can be halved by this arrangement, thus greatly reducing the intensities of creep, residual double refraction, and permanent set. Fig. 4 is a schematic drawing of a reflection polariscope with which both the isoclinics and isochromatic fringes can be observed and recorded with nearly the same ease and manner as in a transmission type.

DEPENDENCE OF DOUBLE REFRACTION ON STRESS

From an engineering point of view it is necessary that double refraction of polarized light in isotropic materials shall be the result of stress rather than strain. It has been generally agreed that in nearly all glasses of various composition this is actually the case, as verified by Filon and Rossi (14) and others. Concerning the synthetic materials, the situation is more complicated. Theories as to the cause of double refraction and its relationship to stress and strain in a synthetic material vary greatly. However, experimental studies of celluloid and bakelite show that both stress and strain are related to double-refraction phenomenon. It will be quite safe to assume that

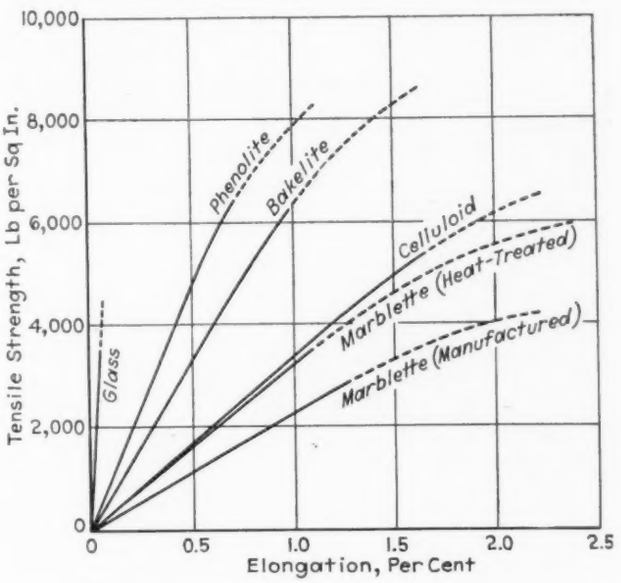

FIG. 3 STRESS-STRAIN CURVES FOR VARIOUS PHOTOELASTIC MATERIALS

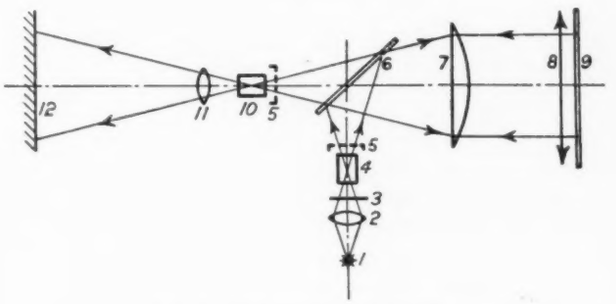

FIG. 4 REFLECTION POLARISCOPE

(1 = source of light; 2 = condenser lens; 3 = filter; 4 = polarizer; 5 = quarter-wave plates; 6 = glass plate; 7 = lens for parallel light; 8 = model; 9 = mirror; 10 = analyzer; 11 = projecting lens; 12 = screen.)

a similar relationship exists for marblette also; an experimental verification is under consideration.

"EDGE STRESS" UNDER AGING

It is generally considered that for short periods of time, e.g., a few weeks, glass does not undergo any optical or physical change. Since in photoelastic investigations the specimen is usually tested within a day or two after cutting and finishing, glass is practically safe against time effect. Synthetic materials on the other hand show aging effect at their edges and surfaces as a result of certain physical or chemical change that develops with time. Bakelite specimens show this effect within about one week, and it can be easily detected from the distortion of the fringes near a boundary line in a fringe pattern as seen in Fig. 5.

FIG. 5 FRINGE PATTERN OF STRESSES IN A CEMENTED SPECIMEN REPRESENTING A WELDED CONNECTION UNDER TENSION

Marblette has been found to show this phenomenon less markedly.

TRANSPARENCY

The degree of transparency may have an important bearing on the brilliancy of image on the screen and the quality of photographic prints of stress patterns. Glass has the highest transparency, followed by marblette, bakelite, celluloid, and phenolite.

BUILT-UP AND REINFORCED MODELS

The necessity of a knowledge of exact stress distribution in built-up models representing structural shapes, space frames, and welded connections is becoming more and more urgent. To build such a model of elaborate construction requires the cementing of the individual members. This must be done under ordinary room-temperature conditions, because any subsequent heating for stronger bond produces undesirable deformations in the members and residual stresses at the cemented joints and along the finished edges, as shown in Fig. 5, taken from a previous investigation by the author (15) of stresses in welded connections. The cement produced by the manufacturers of marblette has been found to act successfully for cold cementing. Incidentally, the same cement is found to be also good for cold cementing of bakelite pieces. Since cemented areas are usually small, the total force that can be applied on these areas has to be small too. With this in mind, for a stress pattern of a sufficiently large number of fringes, the use of marblette for built-up models will be advantageous.

In a preliminary investigation of the stresses in bakelite plates reinforced with aluminum rods (16), it was found that cast plates with a bakelite matrix had high initial stresses due to shrinkage, as is evident in Fig. 6. A similar plate at the right with a marblette matrix is practically free from shrinkage stresses. Although the intensities of these stresses can be computed (17) and corrected, the accuracy of the net stresses due to an applied force will not be very great when the intensity of the initial stress is relatively large as compared with that due to the applied load alone.

Another fact of equal importance that makes marblette desirable for such tests is that it is obtainable in liquid form of proper consistency, ready to be poured into a mold for casting purposes, under ordinary laboratory conditions.

LOW COST

The cost of material is of importance only when models of extensive number and large size are in question. At the present market prices the cost of marblette is about one-third that of bakelite.

OTHER ADVANTAGES OF MARBLETTE

Further advantages of marblette over the other materials used in photoelastic tests will be found in the use of this material in the following new fields of photoelastic investigations:

(*a*) The phenomenon of shrinkage stress upon cooling or setting has further bearing upon the accuracy of results when one considers the investigation of surface stresses in a three-dimensional model by Mesnager's method (18). The process consists in coating a polished metal surface with a transparent isotropic cement that has double refracting properties under an applied force, and then analyzing the induced stresses in this thin film by means of a reflection polariscope. The main difficulty in such a test consisted in finding a cement that would adhere uniformly and effectively to the polished surface. Marblette liquid, if of proper consistency by the addition of

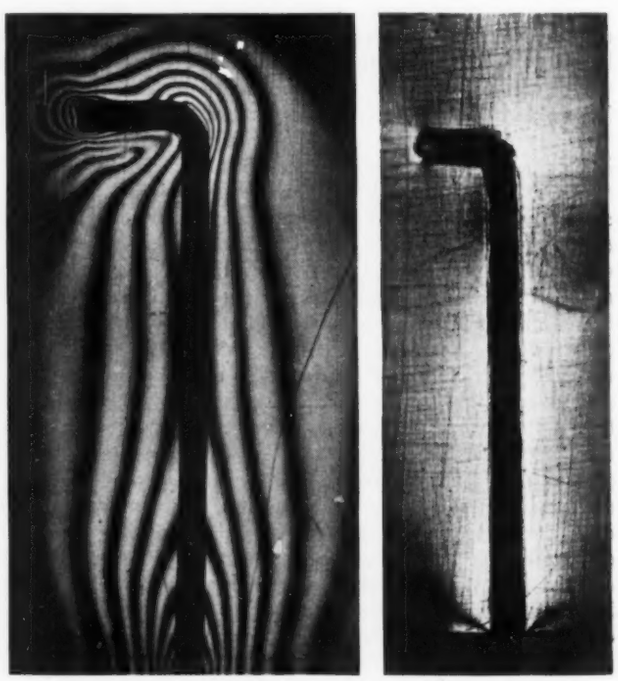

FIG. 6 FRINGE PATTERN OF INITIAL STRESSES IN REINFORCED SPECIMENS RESULTING FROM SHRINKAGE
(Left, bakelite; right, marblette.)

alcohol, is found to adhere to aluminum under proper heating conditions.

(*b*) The experimental investigation of shear-stress distribution in test bars of various geometrical cross sections under torsional strains is of considerable importance to engineers. In early trials with bakelite specimens the author was not successful in getting a fringe pattern with a sufficiently large number of fringes. Marblette, on account of its higher optical sensitivity and larger plasticity at low temperatures, has been found advantageous for this field also.

A $1^1/_4$-in. cylindrical bar 12 in. long was heated gradually to about 180 F and kept there for one hour. After twisting through a small angle, it was held rigidly while being cooled to room temperature. A slice of this specimen about $^1/_4$ in. thick revealed the fringe pattern of the shear stresses as in Fig. 7. Since the fringes are of zero order at the center and increase toward the outer boundary with a quite uniform spacing except near the circumference, where "edge effects" are predominant, this tentative trial checks our theoretical concept of a uniformly increasing shear stress along a radial line, with zero value at center, of a cylindrical bar of circular cross section under pure torsion. Besides shear stress due to torsion, valuable information as to plastic deformations and resulting stress distributions in heated marblette specimens can be obtained by this method.

(*c*) Another important field of experimental investigation where the use of marblette will be welcomed is that of the analysis of gravitational stresses in rotating bodies by means of the centrifuge polariscope method (19), a diagrammatic representation of which is shown in Fig. 8. Because of the limited size and speed of the centrifuge machines and models tested, the gravitational stresses produced cannot be large; hence unless

FIG. 7 FRINGE PATTERN OF SHEAR STRESSES IN A CYLINDRICAL ROD UNDER TORSION

the stress-optical coefficient of the material is high enough, the stress pattern obtained in many investigations will not have a sufficient number of fringes for an accurate solution of the problem. Such was the case in a tentative investigation (19) with bakelite models of a rigid beam and a retaining wall, the latter under sand pressure. If marblette were available for the models, the number of fringes would have been tripled in the pattern, thus offering sufficient data for an experimental analysis.

ACKNOWLEDGMENT

The author is indebted to S. Hansen, president of Marblette Corporation, for cooperation rendered in preparing marblette plates under various curing conditions.

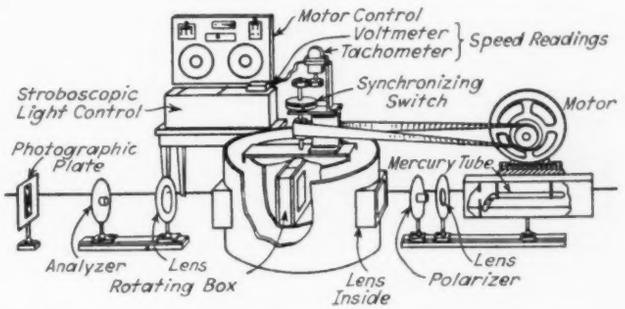

FIG. 8 DIAGRAMMATIC REPRESENTATION OF COMBINED CENTRIFUGAL AND PHOTOELASTIC EQUIPMENT

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Fundamentals of Mechanical DIMENSIONAL CONTROL

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DIMENSIONAL control is the key to the mass production and satisfactory functioning of modern mechanisms. To the engineer who has the responsibility of producing an intricate mechanism, a knowledge of the fundamental principles of dimensional control with a thorough understanding of their applications is a most valuable asset.

The science of dimensional control is both technical and economic, and relates to design, production, and inspection. It has been the author's purpose in preparing this paper to gather together and correlate the fundamental principles pertaining to these various aspects of the subject as they have been enunciated by various workers in this field. There are, in addition, administrative principles to be found in textbooks on quality control which are applicable, but which, for lack of space, can only be referred to incidentally.

Twenty principles, which are numbered consecutively, and several corollaries are stated and are classified under five headings.

BASIC PRINCIPLES OF MECHANICAL PRECISION

High precision in the form and dimensions of parts of mechanisms is now an everyday fact, so that no arguments need be presented as to its desirability in many cases. Fifteen or twenty years ago precision of the order of 0.0001 in. and better was commonly considered to be of academic interest but of extremely little practical importance. To the degree that high precision is technically possible, economic factors now often govern the decision as to how great or how small deviations from the highest degree of precision are practicable.

The first principle concerns the attainment of the highest degree of precision in the production of fundamental mechanical forms. Such forms include straightedges, parallel straightedges, parallel planes, cubes, prisms, angles, wedges, triangles, cylinders, spheres, cones, screws, and gears. Some of these fundamental forms are embodied in dimensional standards, such as precision gage blocks, plain and threaded plug gages, angle standards, and precision micrometer or lead screws.

1—APPLICATION OF GEOMETRICAL PRINCIPLES OF GENERATION TO REDUCE ERRORS

The first principle may be stated as follows:

Fundamental mechanical forms may be produced by applying geometrical principles of generation in a process of abrasion or otherwise forming of surfaces in such a way as to cause symmetrical distribution of errors and to reduce the errors to the vanishing point. Thus by a simple, regular procedure, which contains within itself the elements of precision, errors of form may be reduced indefinitely.

Certain forms may be generated by means of a single flat abrading surface. In such cases two approximately similar bodies are constrained with respect to each other in all six degrees of freedom, and contiguous surfaces of the bodies are abraded by motion along the surface. The surfaces which are thus abraded are interchanged at intervals by a systematic procedure of transposition, and the process is continued until errors of form are reduced to the vanishing point. This method and its application in detail have been described by Wm. E. Hoke (14).[1] He has described the procedure of forming two equilateral triangles, to demonstrate the principle, as follows:

> Cut two pieces of strawboard into a form approximating a 60-deg [equilateral] triangle. Hold the two pieces firmly side by side and rub, successively, all three sides of this double formation on a flat sheet of sandpaper. Then turn one of the pieces 120 deg and continue to rub and turn until they fit each other interchangeably. The result is the production of two equilateral triangles of quite high precision. . . . The same principle can be applied to the production of polygons with any number of sides, reaching the infinite number that results in precision circles or disks.

While this method yields accuracy of form and is applicable in the production of angle standards and straightedges, the resulting linear dimensions, such as the length of a side of the triangle, are not readily controlled. Accordingly, it is more convenient to use two opposed abrading surfaces in the production of precision gage blocks, cylindrical plug gages, or steel balls. In such cases a multiplicity of pieces may be lapped simultaneously, and the pieces allowed to have one or more degrees of rotational freedom, as in the Hoke process of lapping of precision gage blocks (29, 36) or the grinding of steel balls in a ball-grinding machine. Parallelism of the lapping surfaces is maintained by transposition of pieces. Pieces may be lapped singly if the spacing and parallelism of laps is maintained by some other means.

In the lapping of cylinders between plane laps (24) the method is not absolute on account of the fact that constant diameter figures other than cylinders are produced. This effect is called "lobing." The lobing is removed by a hand operation with a ring lap just prior to final finishing between flat laps.

Precision gage blocks, such as the Hoke, Johansson, Van Keuren, Hommelwerke, and other types, consist of rust-resisting steel having surfaces plane, parallel, and a specified distance apart within a few millionths of an inch, and constitute practical standards of length in industry. Such blocks, however, do not constitute length standards until they have been calibrated and certified as to length at the standard temperature of 20 C (68 F) in terms of national or international standards of length.

2—MEASUREMENTS TO MILLIONTHS OF AN INCH BY MEANS OF INTERFEROMETER

Such calibration has been reduced to an engineering pro-

Publication approved by the Director of the National Bureau of Standards, U. S. Department of Commerce, Washington, D. C.

[1] Numbers in parentheses refer to similarly numbered items in the bibliography at the end of this paper.

cedure. That is, means are available which may be applied anywhere, by any one skilled in the art, to determine the length of a precision gage block to a precision of approximately one or two parts in a million. The basis for this procedure is as follows: Nature provides, in the wave lengths of certain monochromatic radiations (spectrum lines) of various chemical elements, standards of length which are readily applicable to determinations of the lengths of contact standards, i.e., precision gage blocks, to the highest precision.

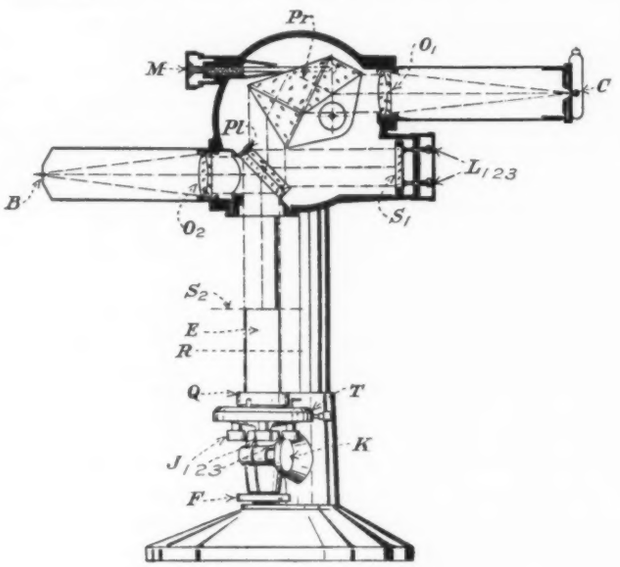

FIG. 1 SECTION OF KOESTERS' INTERFEROMETER

(B = eyepiece; C = lamp; E = gage block; F = elevating screw; J = adjusting screws; M = micrometer screw for prism; Pl = semi-transparent metal film; Pr = prism; Q = base plane; S_1 = mirror with hairline cross; S_2 = upper surface of gage block; T = table.)

The means for doing this is the interferometer, of which there are various designs, coupled with means for accurately controlling and measuring the temperature, and means (a barometer and psychrometer) for determining small corrections to the wave lengths which depend on the refractive index of the air. There are two types of interferometer commonly applied to such measurements, namely, the Fabry-Perot interferometer (28) and the Koesters (18) modification of the Michelson interferometer. The presence of interferometers in the hands of manufacturers indicates that the precise derivation of a length has become a standard engineering procedure, a development made possible by the provisional adoption of the wave length of the cadmium red radiation as a supplementary international standard of length by the International Conference on Weights and Measures.

The radiations commonly used as standards of length are those of cadmium, krypton, helium, neon, and mercury. The iron spectrum is most frequently used as a secondary standard for intercomparing wave lengths of different spectra. The wave length of the red radiation of cadmium has been repeatedly compared with the international prototype meter, first by Michelson in 1893 and most recently in 1933 by Sears and Barrell (33). The average value found for its wave length in normal dry air at 15 C is 0.00064384696 mm. The cadmium red radiation thus has become the primary wave-length standard by comparison with which the wave lengths of other radiations are determined.

The Koesters interferometer is shown in Fig. 1. This instrument may be thought of as a means for laying a scale, consisting of monochromatic wave lengths of light, alongside of the gage block. In fact, not merely one scale is used, but several scales having different lengths of divisions corresponding to the different known wave lengths of spectrum lines. The procedure is to read the displacements of interference fringes, represented in Fig. 2, which are formed by light reflected from the top surface of the gage block and that reflected from the base flat to which the gage is wrung. These displacements represent fractions of wave lengths in excess of some (disregarded) integral number. These fringe fractions are compared with the fractions which would be observed if the block as read were of exactly the correct nominal length. The amounts by which the observed fringe fractions differ from the nominal fractions determine a correction to be applied in computing the exact length of a gage block. A record of such observations and computations that are involved is shown in Fig. 3.

This method may be summarized by the statement of another principle.

3—METHOD OF COINCIDENCES OF EXCESS FRACTIONS

By the method of coincidences of excess fractions (35, 18), a length may be determined more precisely, if it is known approximately, by making successive comparisons of the unknown length with a series of (wave-length) scales, without counting the total number of divisions of any scale in the length to be measured. Each scale has equal divisions of known length, but the divisions of each scale differ in length from those of every other scale.

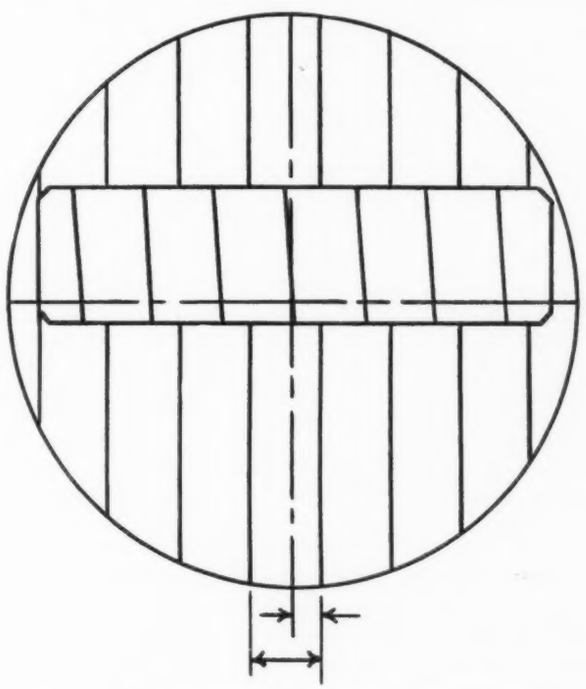

FIG. 2 FIELD OF VIEW IN KOESTERS' INTERFEROMETER

A set of gage blocks thus measured constitutes the crown of a hierarchy of length standards and gages used in a manufacturing plant. Several sets of gage blocks are submitted annually to the National Bureau of Standards for comparison with its set of standards or for direct comparison with wave lengths.

For industrial purposes in this country the inch-millimeter conversion is the relation: 1 inch equals 25.4 millimeters

(ASA B48.1-1933). In practice, Johansson gage blocks have always been made on the basis of this definition (16).

Once a set of gage blocks has been so measured, other blocks to be used as secondary standards can be compared with them by much simpler interference methods and their lengths so determined. Lengths of gage blocks submitted to the Bureau for certification are commonly so determined, whereas the

Nominal size .100 ; Iden. No. 70 ; Date 1/22/34 ; Obs. IHF

Thermometer reading 18.84 / 19.02 °C.; Corr. +0.23°C.; Corr. temp. 19.06 °C.

Barometer "752.10 mm; Therm. 22.2 °C.; Corr. bar. press. 749.04 mm

Psychrometer ": Dry bulb 18.7°C.; Wet bulb 10.8 °C.; Vap. press. 5.8 mm

Helium

	Red	Yellow	Green	Bl. Gr.	Blue	Violet
Fraction of inter. band, obs.	.65	.40	.85	.75	.95	.30
" " " " "	.65	.45	.85	.80	.00	.30
Average, obs.	.65	.42	.85	.78	.98	.30
Nominal fraction	.87	.87	.21	.12	.34	.86
Obs. - Nom. (+)	.78	.55	.64	.66	.64	.44
Nom. - Obs. (-)	.22	.45	.36	.34	.36	.56

Length corr. at 20°C.:

Wave length scale reading = -0.100 u = -0.000,0039 in.

Wave length corr. for temp., bar.press., vap.press. (scale reading) = +0.000,0028 x .100 in. = +0.000,0003

Gage corr. for temp. = +0.000,0115 x 1.13 x .100 in. = +0.000,0013

Corr. for phase change, quartz - steel = +0.000,0025

Total +0.000,0002 in.

Parallelism error across width +0.000,0010 in.

along length - .000,0030 in.

FIG. 3 RECORD OF ABSOLUTE MEASUREMENT OF A 0.1-IN. GAGE BLOCK

(NOTE: The block was measured near the middle of one long edge. Of the corrections the "wave-length scale reading," —0.100μ, is the deviation of the length as read from the nominal (0.100 in.), represented by the "Nom.—Obs." fractions and determined by means of a special slide rule having parallel scales proportional to the wave lengths. The second is a wave-length correction depending on the refractive index of the air. The third is a thermal-expansivity gage-length correction. The total is the deviation of the length of the block from nominal at 20 C.)

standards are remeasured periodically against light waves to ascertain any changes in their lengths.

PRINCIPLES OF TOLERANCES

With further reference to precision gage blocks, the errors in length, parallelism, and flatness of measuring faces can be reduced to the vanishing point but as a matter of actual practice they never are, for economic reasons if not for technical reasons. Gage blocks may be purchased which are accurate to 0.000008 in. per block up to one inch, and per inch of length for longer blocks; also blocks which are accurate to 0.000004 and 0.000002 in. There is probably no occasion which makes it necessary to go beyond such accuracy, but if there were, a handsome price must be paid to obtain it. The first two accuracies stated are the usual commercial accuracies. The variations which are found even in objects of such high precision as gage blocks indicates that in practice there is no such thing as an exact dimension, and that to specify a dimension to be exact or "to size" is a violation of a fundamental principle, which follows.

4—SIZE VARIATION CAN BE RESTRICTED BUT NOT AVOIDED

Variation in the size of a part can be restricted but not avoided; however, a certain amount of variation can be tolerated without impairing the functioning of mechanical parts.

Such permissible variation is technically designated a "tolerance," and the limiting sizes inclosing the zone of the tolerance are the "dimensional limits" or simply the "limits." There are a number of generally accepted principles relative to the application of tolerances or the specification of limits. It must suffice that they be merely stated without much detailed explanation.

5—TOLERANCES MAY BE UNILATERAL OR BILATERAL—SYMMETRICAL OR ASYMMETRICAL

Tolerances may be unilateral with respect to a basic size, i.e., either entirely plus or entirely minus; or they may be bilateral, i.e., both plus and minus; and either symmetrical or asymmetrical with respect to the basic size. Unilateral tolerances in the majority of cases have a considerable number of distinct economic advantages over bilateral tolerances (27, 9).

6—INTERCHANGEABILITY SECURED BY FIXING MAXIMUM METAL LIMITS

To secure interchangeability of parts and avoid the necessity of individual fitting, dimensional limits are so specified as to fix the maximum metal limits of fitting parts, i.e., the minimum external and maximum internal parts.

7—TOLERANCES MOST EFFECTIVE THAT REPRESENT WIDEST PRACTICABLE RANGE OF CLEARANCES OR INTERFERENCES

The minimum clearance or maximum interference between components which operate together is the "allowance." The maximum clearance is the sum of the allowance and the tolerance on each of the component parts. The minimum interference is the allowance minus the sum of the tolerances on the component parts. Therefore, the sum of the tolerances is determined by the differences between the maximum and minimum practicable clearances or interferences between components which operate together (3). This sum may be subdivided equally or unequally, and the fractions assigned to the two mechanical parts, as convenient. When the maximum metal limits have been fixed, the result of this assignment is to fix the minimum metal limits.

Tolerances are more readily and consistently maintained in the production of parts when they represent the widest variations that the proper functioning of the mechanism will permit. Particularly in the manufacture of interchangeable parts in large quantities, tolerances should be based on functional requirements. Tolerances fall into disrepute and tend to be disregarded in the shop when they are unnecessarily small and represent the utmost that can be attained with the manufacturing equipment.

Under the category of functional requirements must be included tolerances which must be applied to apparently unimportant dimensions in order that successive machining operations may be performed satisfactorily in automatic machinery. The telephone furnishes two examples. The thickness of the earpiece of the receiver must be held within close limits in order that the radius of the outside rim will not be off-center and detract from the appearance. Similarly, the diameter of the base must be uniform within close limits or the depth of stamping of the company's name will vary from piece to piece sufficiently to be unsightly.

8—LAWS OF DIMENSIONING

Composite surfaces require dimensions and tolerances so disposed on drawings that the maximum and minimum metal conditions are definitely established.

Composite surfaces are those which are required to maintain a correlation which cannot be expressed by a single dimension. Examples of composite surfaces are tapered surfaces, gear teeth, screw threads, irregular profiles, and the mutual spacing of several holes. Compound tolerances occur when tolerances are placed on two or more dimensions in such a way that two or more answers may be obtained in trying to determine the maximum or minimum metal conditions.

Thus, compound tolerances on composite surfaces are a serious error and must be avoided in specifications and drawings by applying the following laws of dimensioning, stated by E. Buckingham (3):

All points in the same straight line shall be located by dimensions and tolerances with respect to a single locating point or registering surface.

Dimensions shall be given between those points which it is essential to hold in a specific relation to each other.

The basic dimensions given on component drawings should be the maximum metal sizes, i.e., for the minimum hole in the basic-hole system of fits, and for the maximum shaft in the basic-shaft system of fits. Functional requirements sometimes require exceptions to this rule.

Dimensions between the same points shall not be duplicated.

As far as possible, the dimensions on companion parts should be given from the same relative locations.

Equally as important, in production practice, as tolerances on dimensions are tolerances on limits (10). This phrase "tolerances on limits" is based on an old concept loosely covered jointly by the terms "gage tolerances" and "wear limits." The new term was first applied, I believe, by John Gaillard (10), a year or two ago. It embodies a useful concept because under it may be included three items which have commonly been considered separately.

9—TOLERANCES ON LIMITS

The principle of tolerances on limits is: To comply with tolerances on dimensions, in the production of parts, tolerances on limits are a practical necessity to provide for (*a*) gage tolerances, i.e., the unavoidable variations in the sizes of gages, (*b*) wear tolerances for gages, and (*c*) the observational errors in the measurement of gages.

The tolerance on the limit is especially significant when the dimensions of parts are so close to the specified dimensional limit that doubt arises as to whether the parts are within the tolerance or outside of it, and accordingly whether a purchaser of such parts should accept or reject them. The logic of the situation thus presented is the first corollary of this principle.

If the product tolerance is truly the maximum variation in dimension which will permit proper functioning of the mechanism, then the tolerance on the limit can only be unilateral and within the product tolerance, at least with respect to the gage tolerance and gage-wear tolerance (or wear allowance), although it may be bilateral with respect to the errors in measurement of the gage. If any variation beyond the limits other than the last can be tolerated, the product tolerance as established is too small.

This corollary will be discussed after other corollaries to this principle have been stated, as follows:

Gage tolerances are necessary to provide for technically unavoidable or economically necessary variations in gage manufacture.

Definite wear tolerances should be set up for all gages in the factory, including master gages, inspection gages, and working gages (2). A definite time should be set for the inspection of each gage, and a record made of the findings of the inspection, so that the gage will be withdrawn from use at the proper time.

In measuring a gage for wear it is important that the checking tools reach the point of maximum wear in the gage, as inequalities of wear are common.

When measurements of gages yield results which are outside of the gage tolerance (and/or the product tolerance), not more than the certified or known accuracy of such measurements, the gages shall be considered to be within tolerance unless contracting parties have previously agreed otherwise.

For example, if at the Bureau we are authorized to approve or reject a gage which, according to our measurements, is 0.0001 in. outside of the tolerance, and the accuracy to which the measurement can be certified is 0.0001 in., the gage would be approved. If the measurement shows the gage to be 0.00011 in. outside of the tolerance, the gage would be rejected.

With regard to the first corollary of this ninth principle: The gage tolerance itself has generally been kept wholly within the product tolerance in this country, but the practice has been otherwise in foreign countries. The American standard for fits, ASA No. B4a-1925, states that "the extreme sizes for all plain limit gages shall not exceed the extreme limits of the part to be gaged." This principle has also been affirmed in the Report of the National Screw Thread Commission (40). There is, however, a tendency in practice to make the tolerance on the "not go" gage bilateral with respect to the product limit; witness the specification for such tolerance in the proposed international system of fits, or even to place the "not go" gage tolerance entirely outside of the product tolerance, as in the published standards of the General Motors Corporation (26). When the product tolerance is so small that the gage tolerance is a large percentage of it, the manufacturer is apparently robbed of nearly all of his tolerance, and it is on this basis that the practice was adopted. For example, suppose the product tolerance to be 0.0005 in., the "go" gage tolerance plus the wear tolerance is 0.0002 in., and the "not go" gage tolerance is 0.0001 in. This would leave a minimum effective tolerance for the product of 0.0002 in. By putting the "not go" gage tolerance outside of the product tolerance, the effective working tolerance is apparently increased by 50 per cent to 0.0003 in.

If the actual physical characteristics of a gaging operation are considered, the effective product tolerance might be thought of as being reduced by another 0.0001 in. The rule for a "not go" gage is that it shall not enter, or at most it shall not pass through the work. As a matter of fact a plain plug gage, if lubricated, may be readily passed through a ring gage which is actually 0.0001 in. less in diameter than the plug, on account of the elasticity of the materials. Thus it is probably true that a "not go" plug made to 0.0006 in. limit will actually only pass holes which are not more than up to 0.0005 in. limit. However, in view of this fact, what is to prevent the designer from setting the product limit at 0.0006 instead of 0.0005 in. and keeping the gage tolerance within the product tolerance, thus maintaining the integrity of the limits?

It is to be borne in mind that "go" gages wear toward and beyond the maximum metal limit of the product. "Not go" gages wear away from the minimum metal limit and into the product tolerance. Economy in use requires that wear tolerances be provided for "go" gages. The necessity for such a tolerance tends toward the practice of applying a bilateral tolerance to the "go" limit, in that the gage is allowed to wear beyond the limit. For example, C. E. Johansson (16) states that in the Ford Motor Company "the wear-limit size on female gages has been determined as the sum total of the maximum limit plus 20 per cent of the difference between the maximum and minimum sizes." Such a practice must be based on tolerances which are less than the functional require-

ments will permit, and on such a basis the practice may work satisfactorily within a given organization. In other words, the workman is robbed of 20 per cent of the satisfactory tolerance by the drawing instead of by the gage. However, in the manufacture of munitions by a number of contractors during the World War such practice gave rise to numerous difficulties and disputes, both here and abroad. E. C. Peck, when put in charge of gages in the Army Ordnance Department, laid down the ruling (6), "that the component dimensions as represented by master gages must never from any cause whatever be exceeded either from wear of gages or inaccuracy." He stated, "Proof of my statement that the system which I advocate works out is that immediately following its understanding and adoption gage troubles became less and less until finally they were practically nothing. Under the English system they never got any less and there was also a constant quibble over how much over a mark a gage could wear."

PRINCIPLES OF PRECISION IN PRODUCTION OF PARTS

Having considered the subjects of the basis for precision and accuracy, and the application of tolerances, the subject of dimensional control now naturally subdivides into two additional major subdivisions, namely, precision in production methods, including quality of finish of surfaces, and principles of gaging. In some respects these are interdependent, but for simplicity each will be considered separately.

10—PRECISION IN PRODUCTION HAS BEEN INCREASED BY IMPROVED MACHINE TOOLS

With regard to precision in production methods a principle may be stated as follows:

Accuracy in sizing of parts in production has been increased by progressively improving the designs and materials of machine tools, and by incorporating sizing devices in machine tools.

Principles of design involved include close fitting and precision of component parts (15), requisite rigidity, proper dynamic balance of moving parts, reduction or elimination of secular changes in members by proper heat-treatment and seasoning, improvements in materials of cutting tools to increase their wear resistance, such as the use of high-speed steel or tungsten carbide, and frequent, sometimes automatic, correction of cutting-tool forms. An example of the tools and processes applied in maintaining dimensions within specified limits is given in the discussion presented in Appendix 3 of the 1933 Report of the National Screw Thread Commission (40), on the subject, "Control of Accuracy of Thread Elements in the Production of Threaded Product."

Regarding incorporating sizing devices in machine tools, some examples may be cited, such as (4): Devices built into metal-working machines either to stop the machine when the defective work is produced, or act to position the cutting tool so as to maintain a uniform product; a punch and die equipped with scale and end stops (19); a gage that automatically centers a bar in a die for piercing a group of holes, and dials on feed screws with tool-locating stop blocks. Where jigs and fixtures are used, gaging principles are applied practically automatically. A recent development is the use of a light beam and photoelectric cell to control the cutting tool.

There is a corollary to this principle, by Shewhart (34), to the effect that when by such means, as just stated, all assignable causes of variation have been eliminated, so that such variations as remain due to chance causes are within limits which are predictable according to past experience, and the distribution of sizes within those limits accords with the standard "curve of error" or probability curve, then control of variation in size has been attained.

Thus there are criteria, combining statistical theory and experience, according to which it can be determined whether or not control (within definite limits) has been attained.

The advantages accruing from such control are as follows: Reduction in the cost of inspection; reduction in the cost of rejections; attainment of maximum benefits from quantity production; attainment of uniformity without 100 per cent inspection; and possible reduction of tolerances.

11—PARTS INTERCHANGEABLE WHEN CONTROLLED RANGE OF VARIATION IS LESS THAN SPECIFIED TOLERANCE

Control of variation of size in production involves the principle that parts are interchangeable when the controlled range of variation is less than the specified tolerance. When

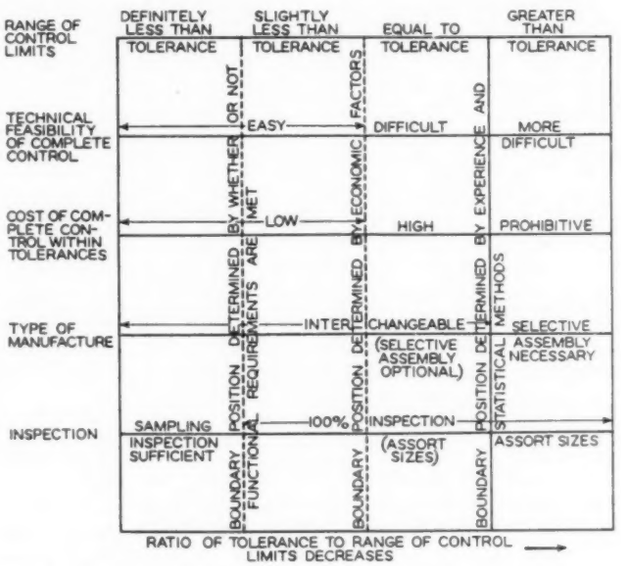

FIG. 4 RELATION OF TOLERANCE TO CONTROL, INSPECTION, AND ASSEMBLY

functional requirements necessitate tolerances which are smaller than the actual range of variation when control has been attained, as defined under 10, it is necessary to abandon strict interchangeability and resort to selective assembly (3, 23, 10). (See Fig. 4.)

For selective assembly the tolerance on each part is divided into zones, the parts are all gaged and assorted as to the zone in which they fall, and companion parts of corresponding zones are assembled. (See Fig. 5.) Examples are piston pins and the pistons or connecting rods with which they are assembled.

The distribution of the parts within the control limits will be in accord with the probability or normal-frequency curve. The range of variation of the product should be made symmetrical with the control limits, if possible. To avoid an excess number of pieces in some one size for which there are no companion parts, the tolerances of companion parts should be divided into equal numbers of zones, regardless of whether or not the tolerances are equal, and not into equal zones in case the tolerances are unequal. Strictly, if the tolerances are unequal, it is impossible to maintain an exactly uniform clearance between all of the parts assembled, if all parts made are to be used. If uniform clearances must be maintained the tolerances must be equal (23).

There is an intermediate territory where selective assembly is optional, depending only on economic factors, and where the tolerance and control range are very nearly equal.

12—WEARING LIFE DEPENDS ON SURFACE FINISH

The standardization of surface finishes and the development of methods of measuring finishes are now receiving considerable attention (5, 17). The A.S.A. Sectional Committee No. B46 on Classification and Designation of Surface Qualities is active in this work (39). An excellent contribution to this subject was a paper presented at the 1930 annual meeting of The American Society of Mechanical Engineers by R. E. W. Harrison (12).

It may be stated as a general principle that the maintenance

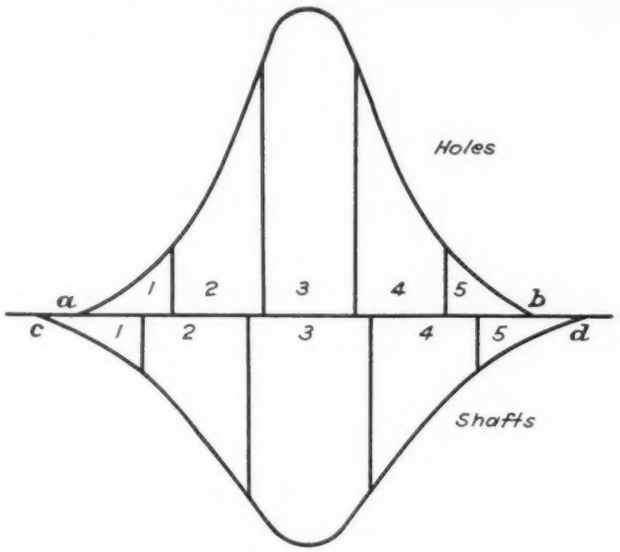

FIG. 5 PARTS DISTRIBUTION IN TOLERANCE ZONES FOR SELECTIVE ASSEMBLY

(*ab* = hole tolerance; *cd* = shaft tolerance. Zones of corresponding numbers are of equal area, indicating equal numbers of parts of the corresponding sizes. Parts in zones of corresponding numbers would be assembled.)

of the clearances of fitting surfaces established as satisfactory or necessary to the proper functioning of a mechanism, and hence the wearing life of the mechanism, depend directly upon the quality of the surface finish, i.e., upon the number, depth, and shape of the scratches per unit area of surface. Moreover, the surface quality to be required must be considered entirely independently of the clearances and tolerances specified for the parts. However, inasmuch as production methods and equipment determine both surface quality and variation in size, the choice of methods and equipment should be such as to assure fulfillment of the specifications for both finish and tolerances.

Mr. Harrison has called attention to a fallacy which commonly exists in the minds of designers, namely, that where tolerances or clearances are large, finishes can be relatively rough. The principal deterioration in a mechanism takes place in the initial wear, when the tops of the ridges wear off and a basically smooth surface is approached. When the ridges are narrow and shallow this smooth surface is quickly reached, but if they are wide and deep the wear will continue rapidly, particularly when subject to high pressure, because fragments of metal torn off remain to act as abrasives which constantly cut new grooves. That such particles are detached in considerable number has been demonstrated by collecting iron particles magnetically in the oil stream of a new automobile engine. That such particles are abrasive has been shown in wear tests conducted by the Bureau; when specimen disks rotating against each other were kept free from abraded particles by light brushing the rate of wear was materially decreased (7).

Polishing or buffing, which is a process of bending the ridges over so that the grooves are filled, generally does not materially increase the wearing life of a surface (12).

The greater wearing life of automobiles produced in the past few years has been cited as being due directly to the improvement in quality of surface finishes (12). The usual method of obtaining finishes of high quality is by means of abrasives. However, high finishes as well as very accurate diameters are imparted, for example, to main bearings of automobile engines by means of a rigidly supported diamond boring tool operated at a high speed with a very fine feed.

An interesting example of variety in finish requirements is the cast-iron piston ring on the surface of which three types of finish are specified. The outside surface is a smooth-turned finish which will promptly wear into conformity with the cylinder walls. The sides are ground to give a close and long-wearing fit with the sides of the grooves in the piston. The inside surface is preferably not machined; the casting skin is allowed to remain although the casting scale is removed. The casting skin aids in giving the ring the proper elastic properties.

PRINCIPLES OF GAGING

The principles of gaging are the counterpart of the principles of precision in production. A gage, as is well known, is a standard of comparison by which dimensions are correlated without yielding a numerical value or measurement. Measurements are a great convenience in reproducing gages or dimensions, but are not strictly necessary because dimensions can be reproduced simply by matching (8). The reproduction of gages by measurements is, however, much simpler than by matching because of the high precision involved. The reproduction of dimensions of parts produced in quantity, on the other hand, is done much more rapidly and conveniently by matching than by measuring.

13—GAGES NECESSARY IN MASS PRODUCTION

Gages are economically necessary in the mass production of mechanical parts, and are usually technically necessary in producing even small quantities of such parts. Gages may be classified as fixed-size, indicating, and progressive.

To quote the report of the National Screw Thread Commission:

> The final result sought by gaging is to secure interchangeability; i.e., the assembly of mating parts without selection or fitting of one part to another, and to insure that the product conforms to the specified dimensions within the limits of variation establishing the closest and loosest conditions of fit permissible in any given case. Gaging should be as much employed to prevent unsatisfactory parts from being produced as to sort out the correct from the incorrect parts.

14—"GO" GAGES CONTROL INTERCHANGEABILITY

Gages representing the limit of maximum metal, known as "go" gages, are required to control the minimum looseness or maximum tightness in the fit of companion parts, and thus control interchangeability. Parts acceptable to correct "go" gages will always assemble. "Go" gages represent the maximum limit of an internal member and the minimum limit of an external member. In gaging a composite surface, such as a screw thread or taper, a "go" gage should check simultaneously as many dimensions or elements as possible.

15—"NOT GO" GAGES CONTROL PROPER FUNCTIONING OF PARTS

Gages representing the limit of minimum metal, known as "not go" gages, are required to limit the amount of looseness between companion parts, and thus control in large measure the proper functioning of the parts. To be acceptable, parts must not enter or be entered by proper "not go" gages. "Not go" gages represent the minimum limit of an internal member and the maximum limit of an external member. To be effective a "not go" gage can check only one element of a composite surface, and to check such a surface completely a variety of "not go" gages may be necessary.

"Go" and "not go" gages, or limit gages, are of the type which may be designated as fixed-size gages. Classes of fixed-size gages are plain gages, such as plain cylindrical plug and ring gages and snap gages, and screw-thread plug and adjustable ring gages. For these types commercial standards have been adopted in this country, published as CS8-33 (ASA B47-1933), "Gage Blanks" (41), a project which was initiated by J. O. Johnson, formerly chief of the gage section, office of the Chief of Ordnance, War Department. Additional non-standardized classes are adjustable thread snap gages, profile gages, such as a simple contour gage or a receiving gage, and position gages for positions of lines, shoulders, or holes, such as the familiar toolmakers' surface gage.

16—PHYSICAL REQUIREMENTS OF FIXED-SIZE GAGES

The physical requirements of a fixed-size gage, in order that it may truly represent a dimension, are that (*a*) it shall either be used at the standard temperature at which its dimension is known or it shall have the same thermal coefficient of expansion as the work gaged; (*b*) the gage shall have high wear resistance and finish; (*c*) dimensional changes in hardening (of steel gages) shall be as small as possible; and (*d*) the gage shall be free from secular changes, i.e., changes of dimensions of gages as they age.

The problem of accurately finishing the gage to size has already been covered by principles Nos. 1 and 10.

To meet the requirement relative to temperature, the Ford Motor Company (16) conveys some parts through constant-temperature rooms where the inspection is performed.

The metallurgical staff (7) of the Bureau has stated that indentation hardness and toughness are important factors affecting wear resistance. Indentation hardness tends to decrease wear as it increases resistance to penetration, scratching, or displacement of the metal. Toughness tends to decrease wear by making it difficult to tear off from the metal the small particles which may be displaced. Also, uniformity of hardness of a gage is important.

Gages which are file-soft have been shown to wear better than gages made from corresponding steels in the file-hard condition, especially in the gaging of hard product (7). However, gage makers and users claim that file-soft gages do not make good gages because they are easily marred, pick up material readily, and do not have a satisfactory "feel."

Just as in component parts, wearing life of gages depends upon quality of finish. As the result of an extended series of tests, L. M. McPharlin (20) concluded that gages with mechanically lapped surfaces have much longer wearing life than hand-lapped gages, which, in turn, excel ground gages. Mr. McPharlin found that mechanical lapping increased wear of plugs from about 1000 holes per 0.0001 in. to between 5000 and 11,000 holes per 0.0001 in.

The accuracy to which a gage represents a dimension is commensurate with the quality of the finish. It is not unusual for the Bureau to find it necessary to refuse to certify a dimension to the accuracy requested because the finish does not justify such accuracy. This is usually because, if a number of measurements of the gage or object are made, the average deviation of the measurements from the mean is greater than the accuracy requested. In the case of precision gage blocks, if the flatness and parallelism errors are large, it is impossible to apply light-interference methods of measurement to the usual degree of accuracy.

Some materials have wear resistance which is superior to hardened tool steel. Tests made by the metallurgical staff of the Bureau have shown that an ammonia-treated chromium-aluminum steel, known to the trade as nitralloy, performed very well in gaging an aluminum alloy and a file-hard carbon steel.

Chromium-plated gages are outstanding in their resistance to wear in gaging steel, aluminum alloy, and cast iron. There was less than 0.00001 in. diameter decrease after gaging 32,000 holes in an aluminum piston alloy with each of two gages. The Ford Motor Company (13) uses chromium-plated gages extensively, and finds that on an average chromium-plated gages give ten times as long service as ordinary tool-steel gages. The type of grinding wheel and proper grinding speeds are important in securing a satisfactory finish on chromium-plated gages, as well as the heat-treatment of the gages before plating. The hardness of chromium plate is increased by an increase in the current density or by a decrease in the temperature of deposition. Advantages gained in the chromium plating of gages, cited by Herschman (13), are: (*a*) The avoidance of elaborate heat-treatments; (*b*) the reduction of warping caused by heat-treating; (*c*) the reclamation of worn gages by re-plating; and (*d*) the avoidance or minimization of the dimensional changes caused by aging effects.

Tungsten carbide contact points, although high in first cost, are being used economically where there is constant production, and excessive wear of gages, particularly where small tolerances are maintained.

Dimensional changes on hardening as well as secular changes (28, 29, 32) are definitely associated with the hardening transformation which occurs in tool steels near the end of the quench, i.e., below 300 C. The control of such changes depends on both the chemical composition and the heat-treatment.

There is considerable knowledge available on this subject as the result of cooperative studies of the Gage Steel Committee (32), organized in 1922, and the Bureau, but it is far from complete. Gage manufacturers each have their favorite and more or less secret procedures, with somewhat varying success (29).

17—INDICATING GAGES—OPTICAL, ELECTRICAL, PHOTOELECTRIC, AND MECHANICAL

A type of gage of equal importance with the fixed-size gage is the indicating gage. Indicating gages are those which exhibit visually, or measure by means of an amplifying mechanism and scale or dial, the variations from uniformity of dimensions or contour. Amplifying or indicating mechanisms are of four general types: optical, electrical, photoelectric, and mechanical.

Thus, indicating gages are intermediary between fixed-size gages and measuring instruments. They differ from measuring instruments in that the dimensional standards to which they are set are not embodied in the gages. However, by means of indicating gages the variations of the work from the size to which the gage is set may be measured. Indicating gages are commonly used merely as limit gages, or to assort work into various size ranges.

Optical gages are among the most precise indicating gages and employ either an optical lever system, an optical projection system, or, more rarely, a system depending upon light-wave interference.

An optical lever system is made up of a light beam and a system of lenses and mirrors. Commercial examples are the pressure tailstock of the Pratt and Whitney measuring machine and the Zeiss optimeter.

An optical projection system is employed in the projection comparator for gaging screw threads, gear-tooth forms, and other small profiles to indicate whether the product is within definite limits on all elements. The apparatus consists of a source of parallel or divergent light, a projection lens system, a support for holding the work in definite relation to the projection lens, a screen onto which the magnified shadow image of the work is projected, and a means for gaging the projected image, as a tolerance chart on the screen representing the limiting outlines of the correct contour.

Electrical indicating gages are of three types: (*a*) those depending upon a change in inductance which unbalances a bridge circuit (21, 22); (*b*) those in which the gage contact point actuates a segmented commutator, the segments of which are connected through lights, relays, or other signaling devices; and (*c*) those depending on capacity changes of condenser plates used as indicators, i.e., ultramicrometers (25, 30).

The first type will accurately produce magnifications from 500 to 100,000 times the movement of the gaging contact point. A 500-cycle alternator supplies electrical energy to a small transformer which in turn supplies energy to four inductances, two of which are small coils in the electric gage head. The inductance of these is varied by the movement of a pivoted steel lever armature, one end of which moves between the coils as the contact point on the other end conforms to the surface of the piece being measured. The other two inductances of the bridge together with the transformer and indicating instrument are mounted on a unit which is placed in easy view of the operator.

One of the most recent developments in ultramicrometers is that by Reisch which gives a straight-line relation between indicator reading and the distance moved by the condenser plate, and eliminates errors of mechanical and temperature disturbances of the moving plate. This design uses two fixed plates with a movable one midway between for the measuring head, and a vacuum-tube bridge as indicator of the differential change in capacity. Maximum sensitivity of the order of 1 or 2×10^{-7} in. can be attained.

Photoelectric gages depend upon the interruption of a light beam, and when used have been embodied in gaging machines, referred to later.

Mechanical indicating gages include: (*a*) Flush-pin and sliding-bar gages; (*b*) test indicators consisting of a gaging contact attached to a lever system or similar amplifying mechanism which operates a pointer relative to a scale or dial sector; (*c*) dial indicators having a rack and gear train or other mechanism by which a pointer is caused to rotate one or more revolutions over a dial; (*d*) a column of liquid, the top of which moves relative to a scale; and (*e*) a spirit level.

An unsolved problem in connection with the third type of mechanical indicators is the design and production of a dial gage of one-half inch range or more which will yield an accuracy comparable to the best of the short-range test indicators, type (*b*), at a reasonable cost.

18—PROGRESSIVE OR COMBINATION GAGES

A third general type of gage is known as progressive or combination gages. A progressive gage is a series of gages assembled into one unit and used for inspecting successively a number of independent dimensions and qualities of the same part. In its more elaborate forms it may be an automatic gaging machine having a hopper into which the parts are fed and from which defective and satisfactory parts emerge separated, and the satisfactory parts are assorted to size.

Gaging machines for steel balls have been in use for more than twenty years (11). The Western Electric Company (31) has been a leader in the development and application of gaging machines, which it uses for parts of telephone equipment. The use of gaging machines is largely governed by economic factors. In addition to those mentioned, an interesting example of gaging machines is a machine used by the Ford Motor Company (37), for inspecting piston pins as to smoothness, hardness, taper, roundness, and diameter, and to assort them as to size in steps of 0.0001 in. In this machine the hardness is checked by means of a scleroscope in which the rebounding hammer operates a photoelectric cell. Some years ago a similar machine, not including the photoelectric cell was put into operation for checking rolls of roller bearings (38). Another example is a machine by Pratt and Whitney Company by means of which a camshaft is compared with a master camshaft.

PRINCIPLES OF MEASURING PHYSICAL DIMENSIONS

The final aspect of dimensional control brings us back to the beginning of this discussion, relative to precision by natural methods. It has been pointed out that the reproduction of gages is simplified by measurements. As an adequate discussion of this division of the subject would be lengthy, a few general statements must suffice.

19—SIX STANDARDS APPLIED IN DERIVING NUMERICAL VALUES FOR PHYSICAL DIMENSIONS

Measurements consist in deriving numerical values for physical dimensions by the application of (8): (*a*) Wave-length standards; (*b*) contact length standards; (*c*) line standards of length; (*d*) precision screws; (*e*) angle standards; and (*f*) combinations of such standards. The corresponding measuring instruments are exemplified in (*a*) the interferometer, (*b*) the end comparator with or without indicating devices for regulating pressure, (*c*) scales, or gages and instruments such as calipers embodying scales or dials, sometimes combined with verniers or indicating devices, (*d*) the micrometer, which also is frequently combined with indicating devices, (*e*) the protractor with or without the vernier and indicating devices, the dividing head, and instruments for deriving angles from length standards, and (*f*) various types of measuring machines such as the universal measuring machine, the screw-thread lead-measuring machine, and the contour-measuring projector.

20—TEMPERATURE AND PRESSURE IMPORTANT

Accurate measurement requires precise control of temperature and measuring pressure.

CONCLUSION

In conclusion, if some aspects of the subject have not been given as full treatment as might be desirable, reference must be made to the literature, and particularly to the references, which have been cited. Bibliographies are given in several of the references. However, with regard to the incorporation of sizing devices in machine tools there seems to be no general treatise available.

The successful manufacture of a mechanism involves th

proper integration of all the factors that have been discussed and much more besides. Such integration must proceed from the point of design and through the entire process; e.g., the design of gages needs to be carried along with the design of the product in just the same way that the methods of machining or established standards of parts and materials must be borne in mind and applied by the designer as he lays out the individual parts.

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Rounded-Approach Orifices

(*Continued from page 760*)

close to the curves in Fig. 1, which is further evidence that Reynolds' number is the correct criterion for use in rounded-approach orifice calibration, whatever the fluid.

TABLE 3 VALUES OF REYNOLDS' NUMBER AND ORIFICE COEFFICIENT

(Taken from the smooth curves of Fig. 1)

Small orifice (d = 0.125 in.)		Medium orifice (d = 0.250 in.)	
Re	c	Re	c
1.11[a]	0.08	50	0.55
12.00[a]	0.25	78	0.60
18.00	0.30	240	0.70
42.00	0.40	820	0.80
100.00	0.50	4500	0.90
230.00	0.60	11500	0.93
500.00	0.70	....	....
1500.00	0.80	....	....
5400.00	0.90	....	....

[a] The equation of the line joining these points is $c = 0.077\ \mathrm{Re}^{0.48}$

Table 3 gives values of Reynolds' number and orifice coefficient taken from the smooth curves in Fig. 1 to simplify replotting.

KREITNER'S DIAGRAM *for* WATER-HAMMER PROBLEMS

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IN RECENT discussions on water hammer, references have been made to a paper entitled "Druckschwankungen in Turbinenrohrleitungen," by Hans Kreitner, St. Polten, Austria, published in *Die Wasserwirtschaft* for 1926, p. 258. When the writer of this review was preparing his paper entitled "Simple Graphical Solution for Pressure Rise in Pipes and Pump Discharge Lines," read before the Engineering Institute of Canada on Feb. 8, 1935, access to Kreitner's work was not possible and it appears to have been incorrectly referred to in the discussion of the latter paper.[1]

After many unsuccessful attempts to get a copy of Kreitner's paper in America, the writer looked it up when on a visit to Berlin this summer and found that it contained an original form of diagram for water-hammer problems that differed from those recently discussed. Inasmuch as the diagram is useful for certain types of problem, a brief explanation of it is given in the following review of the paper.

The writer has also prepared a complete English translation of Dr. Kreitner's paper, which is on file in the Engineering Societies Library, New York.

In the present review much material presented in the paper must be omitted. Persons interested in the subject will find the entire paper worth reading. After considerable discussion of the phenomena attending water hammer, and also of the velocity of wave propagation and of the general equations, the construction of the diagram is explained. It is assumed that the reader knows the literature on water hammer, so that only the briefest outline is given here, and, except where otherwise stated, the original notation has been transformed into that advocated in the 1933 "Symposium on Water Hammer," published by The American Society of Mechanical Engineers.

In the "Symposium on Water Hammer" Equations [1] and [3] on page 15 give

$$h_n - h_0 = h_{max} - \frac{a}{g} V_n - 2\sum (h_{n-1})$$

$$= \frac{aV_0}{g} - \frac{a}{g} V_n - 2\sum (h_{n-1}) \ldots\ldots [1]$$

in which h_n is the pressure rise up to the end of the nth interval, V_n is the pipe-line velocity in the nth interval, and h_0 the initial rise, which is ordinarily zero if the reservoir level is constant; friction is neglected. The symbol a represents the velocity of the pressure wave.

From the same authority Equation [4] (corrected) is

$$V_n = V_0 \tau_n \sqrt{\left(\frac{H_0 + h_n}{H_0}\right)} = V_0 \tau_n \sqrt{\left(1 + \frac{h_n}{H_0}\right)} \ldots\ldots [2]$$

where τ_n is the ratio of the actual gate-opening area to the maximum area, after both have been modified by the proper coefficient of discharge.

[1] *Engineering Journal*, May, 1935, p. 266.

Substituting in Equation [1] and making $h_0 = 0$ gives

$$h_n = \frac{aV_0}{g} - \frac{aV_0}{g} \tau_n \sqrt{\left(1 + \frac{h_n}{H_0}\right)} - 2\sum (h_{n-1}) \ldots\ldots [3]$$

Dividing through by H_0 and writing $K = aV_0/2gH_0$ gives

$$\frac{h_n}{H_0} = 2K - 2K\tau_n \sqrt{\left(1 + \frac{h_n}{H_0}\right)} - 2\sum \left(\frac{h_{n-1}}{H_0}\right) \ldots [4]$$

In order to shorten the formula, Dr. Kreitner has written $\epsilon = h/H_0$, and this symbol will be used here. If this formula is applied successively to the first, second, third, etc., intervals, it gives

$$\left.\begin{aligned}
\epsilon_1 &= 2K - 2K\tau_1 \sqrt{(1 + \epsilon_1)} \\
\epsilon_2 &= 2K - 2K\tau_2 \sqrt{(1 + \epsilon_2)} - 2\epsilon_1 \\
\epsilon_3 &= 2K - 2K\tau_3 \sqrt{(1 + \epsilon_3)} - 2\epsilon_1 - 2\epsilon_2 \\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
\epsilon_n &= 2K - 2K\tau_n \sqrt{(1 + \epsilon_n)} - 2\Sigma(\epsilon_{n-1}) \\
\epsilon_{n+1} &= 2K - 2K\tau_{n+1} \sqrt{(1 + \epsilon_{n+1})} - 2\Sigma(\epsilon_n)
\end{aligned}\right\} [5]$$

By subtracting the last two formulas in Equation [5] the following equation results:

$$2K\tau_{n+1} \sqrt{(1 + \epsilon_{n+1})} + \epsilon_{n+1} = 2K\tau_n \sqrt{(1 + \epsilon_n)} - \epsilon_n \ldots [6]$$

The expression may be somewhat simplified in appearance by writing

$$\alpha = 2K\tau \sqrt{(1 + \epsilon)} + \epsilon \ldots\ldots [7]$$

and

$$\beta = 2K\tau \sqrt{(1 + \epsilon)} - \epsilon \ldots\ldots [8]$$

Inspection of Equation [6] shows that

$$\alpha_{n+1} = \beta_n \ldots\ldots [9]$$

GRAPHICAL SOLUTION

The series of Equations [5] cannot be solved for ϵ by a slide rule, and hence Dr. Kreitner constructed a diagram similar to that shown in Fig. 1. (The writer has drawn only a few of the lines and the diagram may easily be extended and made with lines as close together as desired.) The solid lines are those of constant values of α while the dotted lines are those with constant β, the horizontal axis representing values of $2K\tau$ while the vertical axis gives values of ϵ. The numerical value to which each line corresponds is readily found, since at $\epsilon = 0$ it is seen that $\alpha = \beta = 2K\tau$.

The diagram is best explained by the use of Kreitner's example. A penstock 1610 ft long, under a head of 164 ft, has water at an initial velocity of 6.56 fps stopped in 5 sec, the gates closing at a uniform rate. It is required to plot the pressure rise at half-second intervals; a will be taken at 3216 fps. These data give a value of $2L/a = 1$ sec and $K = (3216 \times 6.56)/(2 \times 32.16 \times 164) = 2$.

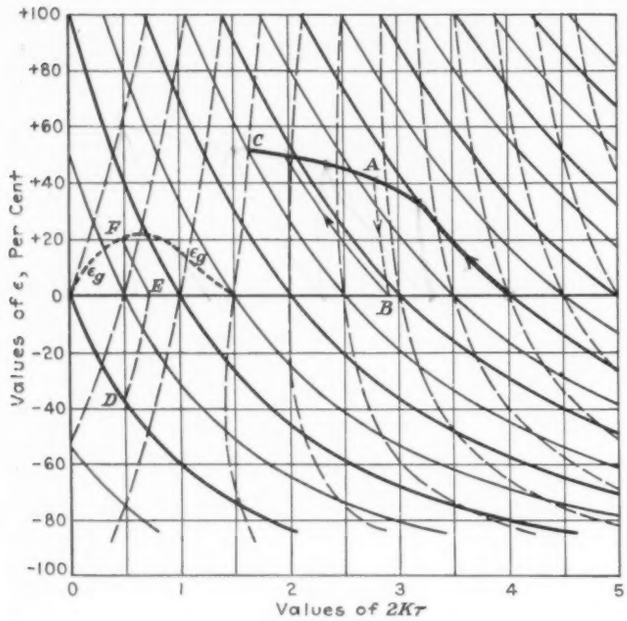

FIG. 1 KREITNER'S DIAGRAM

———— $\alpha = 2K\tau\sqrt{(1+\epsilon)} + \epsilon = \text{const}$

– – – – – $\beta = 2K\tau\sqrt{(1+\epsilon)} - \epsilon = \text{const}$

At each half-second interval after closure begins, the following are found:

$t =$	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
$2K\tau =$	4	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0

Only part of the solution is shown. Starting at $\epsilon = 0$ and $2K\tau = 4$, the heavy line shows the procedure up to $2K\tau = 3.2$, from here one would proceed down a β-line to $\epsilon = 0$, then up an α-line until the condition $2K\tau = 2.4$ is reached, then in the same way to the final value $2K\tau = 0$. Thus A is the pressure at $t =$ 1.5 sec, and from A the line A-B is drawn to represent Equation [8], following which B-C is drawn to represent Equation [7], terminating at C where $2K\tau = 2$. The value of ϵ corresponding to C is evidently 0.485, so that $h/h_0 = 0.485$ at the end of 2.5 sec, and so on. The pressures at the ends of the first, second, etc., intervals are easily found, since the values of ϵ are respectively 0.322, 0.465, 0.495, etc., and the results at the half intervals are easily read off; e.g., at $t = 0.5$ sec, $\epsilon = 0.146$; at $t = 1.5$ sec, $\epsilon = 0.400$, etc.

Dr. Kreitner shows how the nature of the resulting pressure curve may be predicted, but this need not be discussed here.

In Fig. 2, which is also redrawn from the original paper, the method of finding the pressure changes with nonuniform gate movement is shown; the lower portion of this figure is from the diagram of Fig. 1 with all unnecessary lines omitted. The gate-closure curve is always bent near the horizontal axis, just where closure starts, because of inertia and slackness in the mechanism of the governor and servomotor.

The original paper also mentions the "counterblow," which occurs after opening under certain conditions. The effect of this is shown on the dotted curve ϵ_g on Fig. 1, and the method of construction of the curve is indicated for one case. The curve is plotted by making 0-D and E-F, α-lines, and D-E a β-line, while F is vertically above D. The curve shows that the maximum counterblow is $\epsilon_g = 0.23$ and occurs where $2K\tau$ has a value of about 0.6.

The diagram may be used for gate openings as well as closure. Thus, suppose that the gate at the end of a pipe line is opened linearly in two intervals of $2L/a$ sec each, and that the data are such as to give a value of $K = aV_0/2gH_0 = 0.50$. The pressures will be determined at the end of each interval, so that the values of $2K\tau$ will be 0.50 and 1.0, respectively. Starting at 0 and proceeding down an α-line till $2K\tau = 0.5$ is reached, the corresponding value of $\epsilon = -0.39$; from this point a β-line is followed to the place $\epsilon = 0$ and from the latter point an α-line is followed till it intersects the line $2K\tau = 1$, at which

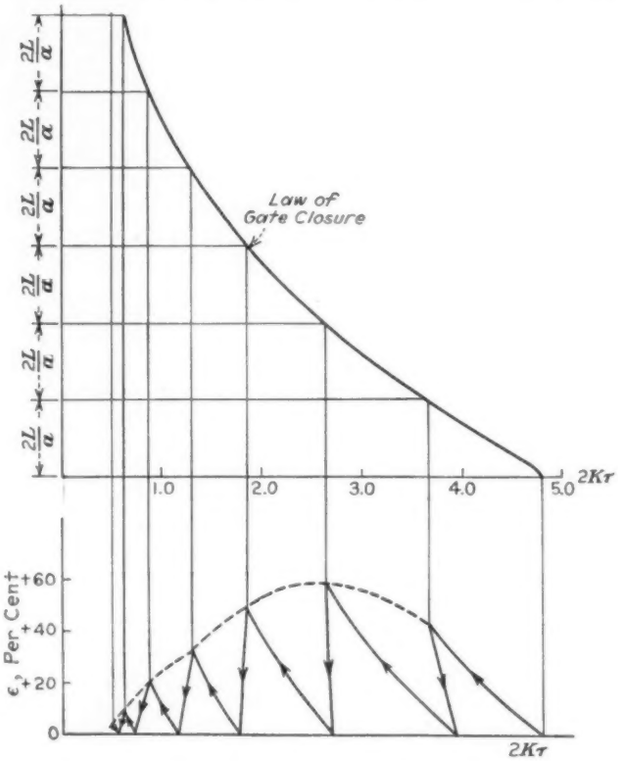

FIG. 2 PRESSURE CHANGES WITH NONUNIFORM GATE MOVEMENT

point $\epsilon = -0.15$ approximately. At the end of the first and second intervals the pressures at the gate end of the pipe are $0.61H_0$ and $0.85H_0$, respectively.

It is easily seen from the diagram that for linear opening the minimum pressure is reached at the end of the first interval.

The Security Markets

(*Continued from page 766*)

valuation activity, directing the flow of savings into proper industries. At the same time the authors conclude that manipulation and uninformed speculative buying operate many times to bring about exactly opposite results and throw the cost of such excessive and undesirable speculation on investors whose market is destroyed by the forced liquidation that follows. Short selling is recognized as being desirable in a free market, but it is recommended that it be so regulated that the manipulative activities of pools may be restrained. This recommendation has, of course, been carried out in the present law, as have most of the other recommendations offered in the concluding chapters.

ENGINEER REGISTRATION LAWS

A Digest Prepared as an Appendix to the 1935 Report of the Committee on Professional Recognition of the Engineers' Council for Professional Development

By P. H. DAGGETT

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THREE years have elapsed since the last detailed analysis was made of engineering registration laws.[1] Since that time the number of states having these laws on their statute books has increased thirty per cent, and nine of the laws have been amended. Engineering registration laws in one form or another are now in force in all but thirteen states, five west of and eight east of the Mississippi. In only two of these states, New Hampshire and Vermont, has there been no agitation for registration laws.

The object of this digest is threefold: (1) To provide engineers in a given state with the essential information regarding the requirements and cost of registration in any other state; (2) to serve as a guide for those promoting registration laws in states which do not now have them; and (3) to provide a comprehensive picture of the present status of the engineering-registration movement (October, 1935). In preparing the digest the writer has had the assistance of T. Keith Legaré, Secretary of the National Council of State Boards of Engineering Examiners.

Every effort has been made to present data, the accuracy of which may be relied upon. To this end some of the data, in particular those in Tables 3 and 4, have been verified by the secretaries of the several state boards, with the exception of those states in which laws were only recently passed. The data for Table 5, columns 6 and 7 of Table 6, and columns 5 and 6 of Table 7 were obtained by means of a questionnaire sent to the secretaries. No replies were received from Mississippi and Tennessee, but the latest available figures indicate that the number of registered engineers in these two states is now less than five hundred. Allowing for multiple registrations, therefore, it is evident that the number of registered engineers at this time is not far from 35,000, although some 50,000

[1] "Engineer Registration Laws," by Blake R. Van Leer, MECHANICAL ENGINEERING, vol. 54, no. 5, May, 1932, pp. 320–322 and 375.

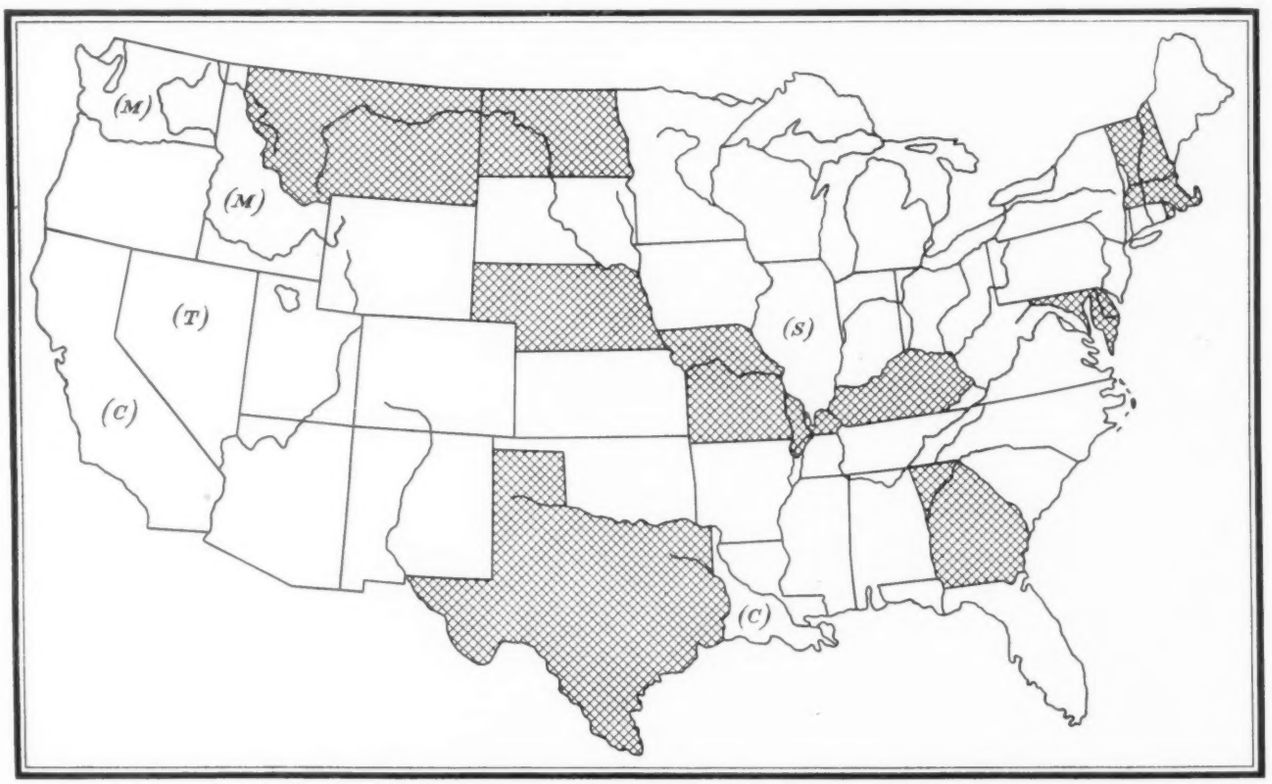


FIG. 1 STATUS OF ENGINEERING REGISTRATION IN THE UNITED STATES, SEPTEMBER, 1935

[(C) = civil engineering only; (S) = structural engineering only; (M) = excluding mining engineering; (T) = restricts use of title only; shaded areas indicate nonregistration states.]

licenses have been granted since the registration movement started. As soon as the seven new boards complete their initial registrations, the number of registrants may be safely estimated at about 38,000.

In Table 2, column 8 gives the per diem compensation allowed to board members over and above necessary expenses which are allowed in all cases. In Table 3, the figures in column 2 are the fees that must accompany the application for registration. Where no fee is indicated, the fee given in column 3 must accompany the application, and unless otherwise indicated in the notes, this fee is returned in case the applicant fails to qualify. The reciprocal fees given in column 5 are the total fees required of applicants from without the state who wish to qualify under the reciprocity provisions, or by means of a certificate of qualification from the National Bureau of Engineering Registration.

The data in column 4 of Table 7 give the number of members in the five professional societies which are represented in the Engineers' Council for Professional Development, for which body this digest was originally prepared.

TABLE 1 ENACTMENTS AND SCOPE OF LAWS

(1)	(2) Date of enactment	(3) Year amended	(4) Type of registration
Alabama	1935	.....	Prof engr
Arizona	1921	'23, '28, '35	Prof engr
Arkansas	1925	None	Prof engr
California	1929	'31, '33, '35	Civil engr (*a*)
Colorado	1919	'21, '27, (*b*)	Engr
Connecticut	1935	.....	Prof engr
Florida	1917	'25, '31	Prof engr (*c*)
Idaho	1919	'21, '25, '29	Civil engr (*d*)
Illinois	1915	'19, (*e*)	Structural engr
Indiana	1921	'35, (*f*)	Prof engr
Iowa	1919	'24, '27, '31	Prof engr (*g*)
Kansas	1931	None	Prof engr (*h*)
Louisiana	1908	'14, '20, (*i*)	Civil engr
Maine	1935	.....	Prof engr
Michigan	1919	None	Engineer (*j*)
Minnesota	1921	'33	Prof engr
Mississippi	1928	'32	Prof engr
Nevada	1919		Prof engr (*k*)
New Jersey	1921	'23, '26, '27	Prof engr (*l*)
New Mexico	1935	.....	Prof engr
New York	1920	'21, '27, '31, '32, '35	Prof engr
North Carolina	1921	None	Engineer
Ohio	1933	'35	Prof engr (*m*)
Oklahoma	1935	.....	Prof engr
Oregon	1919	'21, '25	Prof engr
Pennsylvania	1921	'27, (*n*)	Prof engr
South Carolina	1922	'28	Prof engr
South Dakota	1925	None	Prof engr
Tennessee	1921	'25	Engineer
Utah	1935	.....	Prof engr
Virginia	1920	'24	Prof engr
Washington	1935	.....	Prof engr (*o*)
West Virginia	1921	'31, '35	Prof engr (*p*)
Wisconsin	1931	'35	Prof engr
Wyoming	1907	'17, '19, '25	Prof engr

SUMMARY OF TYPES OF REGISTRATION

Engineer (unclassified)	3
Engineer (classified)	1
Professional engineer (unclassified)	20
Professional engineer (classified)	6
Professional engineer (title protection)	1
Civil engineer	3
Structural engineer	1
Total	35

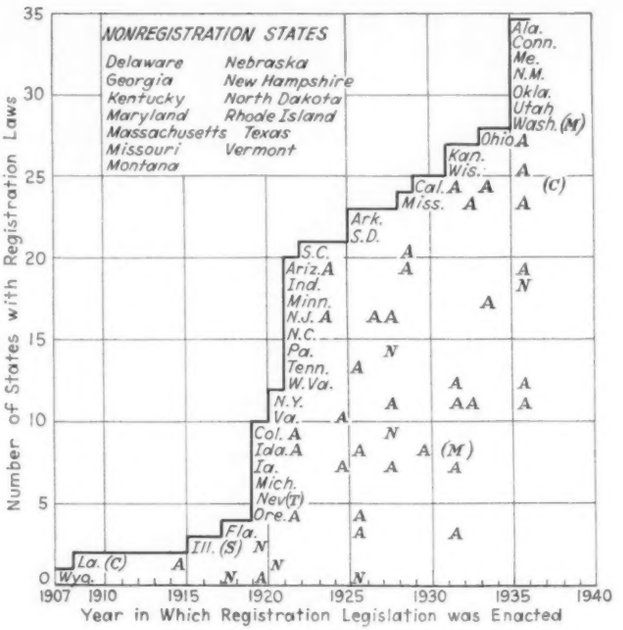


FIG. 2 PROGRESS OF LAWS GOVERNING PRACTICE OF ENGINEERING—COMPILED BY P. H. DAGGETT, 1935

[(C) = law embraces civil engineering only; (M) = law excludes mining engineering; (S) = law embraces structural engineering only; (T) = law embraces use of the title "registered professional engineer" (not compulsory); A = law amended in year indicated; N = new law passed in year indicated.]

NOTES TO ACCOMPANY TABLE 1

(*a*) California: No person shall use the title "structural engineer" unless he is a registered civil engineer, and unless he is found qualified as such structural engineer according to rules and regulations of Board.

(*b*) Colorado: New law passed in 1927.

(*c*) Florida: Certificates read "professional engineer"—registered to practice . . . (any one of the five branches, civil engineering, mechanical engineering, electrical engineering, mining and metallurgical engineering and chemical engineering). Nine special fields are recognized in civil engineering, six in mechanical engineering, four in electrical engineering and one in mining engineering.

(*d*) Idaho: Civil engineering is defined as the practice of any branch of the profession of engineering, other than mining, metallurgical, and military.

(*e*) Illinois: New law passed in 1919.

(*f*) Indiana: New law passed in 1935.

(*g*) Iowa: In the roster, registered engineers are classified into 21 branches of engineering; maximum of five for any one individual.

(*h*) Kansas: The law requires registration in a definite branch or branches of engineering. The policy of the board is to limit registration to a single branch in which the applicant is best qualified, or which most nearly covers his present field of practice. The law is permissive not compulsory.

(*i*) Louisiana: New law passed in 1920.

(*j*) Michigan: The Board has the power to classify applicants into the respective branches of engineering, as follows: civil engineer, mining engineer, mechanical engineer, electrical engineer, chemical engineer, and such other branches of engineering as the Board may consider subject to the act.

(*k*) Nevada: The law is not compulsory. No person may use the title "registered professional engineer" unless registered.

(*l*) New Jersey: See note (*j*) under Michigan.

(*m*) Ohio: The Board is "authorized to designate the various branches of professional engineering and to classify the applicant in the branch or branches for which he is qualified to register."

(*n*) Pennsylvania: Original law declared unconstitutional and new law passed in 1927.

(*o*) Washington: Members of the American Institute of Mining and Metallurgical Engineers are exempted.

(*p*) West Virginia: The certificate authorizes the practice of "professional engineering" in the branch or branches of engineering for which, in the opinion of the Board, said applicant shows proper qualifications.

TABLE 2 THE REGISTRATION BOARDS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			—Experience—				
	Number of members	Age	Minimum, yr	Responsible charge, yr	Resident of state, yr	Citizenship	Compensation, per diem
Alabama	5	..	12	5	Yes	U. S.	$ 5
Arizona	7 (a)	35	10	...	3	U. S.	No
Arkansas	5	35	10	...	3	U. S.	No
California	3	30	12	...	5	U. S.	$25
Colorado	5 (b)	..	10	5	Yes	U. S.	No
Connecticut	5	..	10	Yes	10	...	No
Florida	5 (c)	35	10	...	3	...	No
Idaho	3 (d)	..	10	...	1	...	$10
Illinois	5 (e)	..	..	...	...	...	...
Indiana	5 (f)	..	10	5	Yes	U. S.	$10
Iowa	5 (g)	35	10	2	3	...	$10
Kansas	5 (h)	35	10	3	3	U. S.	$ 5
Louisiana	5 (i)	..	..	...	...	...	$10
Maine	5	..	12	5 (j)	Yes	U. S.	No
Michigan	7 (k)	..	10	...	...	...	No
Minnesota	7 (l)	..	10	5	Yes	U. S.	$10
Mississippi	5 (m)	32	10	5	5	U. S.	No
Nevada	5 (n)	..	..	...	...	...	No
New Jersey	5 (o)	..	10	5	Yes	U. S.	No
New Mexico	5 (p)	..	12	5 (p)	Yes	U. S.	$ 5
New York	3 (q)	..	10	5	Yes	U. S.	(q)
North Carolina	5 (r)	..	10	...	Yes	U. S.	$10 (r)
Ohio	5 (s)	..	12	5 (s)	Yes	U. S.	$10
Oklahoma	5	35	10	5	5	U. S.	No
Oregon	9 (t)	35	10	...	1	...	No
Pennsylvania	(u)	..	..	...	...	...	(u)
South Carolina	5 (v)	35	10	...	3	...	$10
South Dakota	5 (w)	35	10	...	Yes	...	No
Tennessee	6 (x)	35	10	5	5	U. S.	No
Utah	7 (y)	..	12	5 (y)	Yes	U. S.	...
Virginia	9 (z)	..	10	...	...	...	$10
Washington	5 (A)	..	7	...	5	U. S.	$10
West Virginia	5	..	10	5	Yes	U. S.	...
Wisconsin	9 (B)	..	10	5	1	U. S.	No
Wyoming	3 (C)	..	10	5	5	U. S.	$10
Model Law	5	..	12	5 (D)	Yes	U. S.	...

NOTES TO ACCOMPANY TABLE 2

(a) Arizona: The dean or assistant dean of the College of Mines and Engineering at the University of Arizona, ex-officio.

(b) Colorado: Including the state engineer, who is secretary-treasurer of the Board.

(c) Florida: Three civil engineers, one mining or electrical engineer, and one mechanical engineer or naval architect. The Board members must also be members "in good standing of a recognized engineering society."

(d) Idaho: Designated "from time to time by the Commissioner of Law Enforcement."

(e) Illinois: Under the Department of Registration and Education.

(f) Indiana: At least two professional engineers and two land surveyors.

(g) Iowa: Must be members "in good standing of a recognized state or national engineering society. No two members of said board shall be from the same branch of the profession of engineering."

(h) Kansas: Same as Iowa; "provided the responsible charge of engineering teaching in a recognized engineering school shall be construed as responsible charge of work."

(i) Louisiana: "All members shall be appointed by the governor of the state from a list presented by the Louisiana Engineering Society."

(j) Maine: Including responsible charge of teaching.

(k) Michigan: Five engineers and two architects; "one of the appointees shall be from the Upper Peninsula."

(l) Minnesota: Three engineers, three architects, and one land surveyor. Not more than one member from the same branch of the profession of engineering. Must be members "in good standing of a recognized society of architects, engineers, or land surveyors."

(m) Mississippi: No two from the same Congressional District.

(n) Nevada: "All of whom shall be engaged in the practice or teaching of professional engineering in any of its branches, excepting military. Members of the board shall, as far as practical, consist of one member of the following engineering professions: mining, hydraulic, electrical, civil or highway, and mechanical."

(o) New Jersey: With the advice and consent of the senate.

(p) New Mexico: Three professional engineers, one land surveyor, and the state engineer, who is ex-officio secretary of the board. "Responsible charge of engineering teaching may be construed as responsible charge of important work."

(q) New York: "Three or more members as designated by the Regents." Actually five members.

(r) North Carolina: At least one member from the engineering faculty of the North Carolina State College, and at least one member from the engineering faculty of the University of North Carolina. Not more than three members from the same branch of the profession of engineering. Per diem now fixed at $7 by general state law.

(s) Ohio: "Four professional engineers and one surveyor. Responsible charge of engineering teaching shall be construed as responsible charge of important engineering work."

(t) Oregon: "Said Board to consist of two civil engineers, two mechanical engineers, one electrical engineer, two hydraulic engineers, and two mining engineers."

(u) Pennsylvania: Provided for in a separate act.

(v) South Carolina: Three civil engineers, one mining or electrical engineer, one mechanical engineer or naval architect.

(w) South Dakota: "Two members of the Board shall be professional architects, three members of the Board shall be professional engineers, and one land surveyor."

(x) Tennessee: One architect and one engineer from each of the "three grand divisions of the state."

(y) Utah: "From a list of fourteen nominees furnished and certified to the Director of Registration as follows: by the Utah section of the American Society of Civil Engineers, four civil engineers; by the Utah chapter of American Institute of Electrical Engineers, four electrical engineers; by the Utah section of The American Society of Mechanical Engineers, four mechanical engineers; and by the Utah Society of Engineers, two land surveyors. At all times the members of the committee shall be two civil engineers, two electrical engineers, two mechanical engineers, and one land surveyor."

(z) Virginia: Three engineers, three land surveyors, and three architects.

(A) Washington: An examining committee appointed by the director of licenses. Not more than two members from the same branch and not more than one land surveyor.

(B) Wisconsin: The state architect, the state engineer, the dean of the College of Engineering of the State University, three architects, and three civil engineers.

(C) Wyoming: The state engineer and two registered professional engineers, one of whom shall be both a land surveyor and a professional engineer.

(D) Model Law: "Responsible charge of engineering teaching may be construed as responsible charge of important engineering work."

TABLE 3 APPLICATION, REGISTRATION, AND RENEWAL FEES

(1)	(2) Application	(3) Certificate	(4) Total	(5) Reciprocal	(6) Renewal (annual)
Alabama	$15	$10	$25	$10	$ 5
Arizona	...	$15*	$15	$ 5	$ 5
Arkansas	$15	$10	$25	$10	$15 (a)
California	$15	$10 (b)	$25	$10	$ 5
Colorado	...	$15	$15	$15	$ 5
Connecticut	$ 5 (c)	$10	$15	$10	$ 2
Florida	$15	$10	$25	$25	$ 5
Idaho	...	$25 (d)	$25	$25	$ 2 (d)
Illinois	$10	$ 5	$15	$15	$ 1 (e)
Indiana	$10	$15	$25	$25	$ 5
Iowa	$15	$10	$25	$10	$ 2 (f)
Kansas	...	$25 (g)	$25	$10	$ 2 (g)
Louisiana	...	$25	$25	$15	$ 1 (h)
Maine	$ 7.50	$ 7.50	$15	$15	$ 3 (i)
Michigan	$ 5	$15	$20	$20	$ 1 (j)
Minnesota	...	$10	$10	$10	$ 3 (k)
Mississippi	...	$25 (l)	$25	$25	$ 5 (l)
Nevada	...	$15	$15	(m)	$ 2.50
New Jersey	...	$25	$25	$25	$ 1
New Mexico	$10	$ 5	$15	$10	$ 5
New York	...	$25 (n)	$25	$25	$ 1
North Carolina	...	$25	$25	$25	$ 5
Ohio	$ 5	$10	$15	$10	$ 1.50 (o)
Oklahoma	...	$25	$25	$25	$ 5
Oregon	$10	$ 5	$15	$15	$ 3
Pennsylvania	...	$20 (p)	$20	(p)	$ 1
South Carolina	$15	$10	$25	$25	$ 5
South Dakota	$20	$ 5	$25	$10	$ 5
Tennessee	...	$25 (q)	$25	$25	$ 5
Utah	$10	$ 5	$15	$10	(r)
Virginia	...	$25 (s)	$25	$25	$ 5
Washington	...	$15	$15	$15	$ 3
West Virginia	$ 5	$ 5	$10	$ 5	$ 5
Wisconsin	$ 5	$ 5	$10	$10	$ 2.50 (t)
Wyoming	...	$15 (u)	$15	$10	$ 2.50 (u)
Model Law	$15	$10	$25	$10	$ 5 (v)

NOTES TO ACCOMPANY TABLE 3

(a) Arkansas: Maximum fee allowed in law. Present fee $2.

(b) California: No person shall use the title "structural engineer" unless he is a registered civil engineer in this state and, furthermore, unless he has been found qualified as such structural engineer according to rules and regulations established therefor by the Board. Application for authority to use this title shall be accompanied by a fee of $10.

(c) Connecticut: $10 for combined engineering and land surveying.

(d) Idaho: Fee not returned on failure to qualify. Reexamination fee $10. Renewal fee $10 after October 1.

(e) Illinois: After August 1 "restoration fee" of $5.

(f) Iowa: After December 1, $10 penalty plus $2 fee.

(g) Kansas: $15 returned on failure to qualify. Reinstatement fee of $10 after 90 days from due date.

(h) Louisiana: After February 1, $10.

(i) Maine: Not more than $3 nor less than $1.

(j) Michigan: $5 every 5 years beginning January 1, 1930.

(k) Minnesota: After January 1, $5.

(l) Mississippi: 50 per cent returned on failure to qualify. Renewal fee $10, 60 days after January 1.

(m) Nevada: No provision for reciprocity.

(n) New York: Fee not returned on failure to qualify.

(o) Ohio: Maximum of $3 allowed; no fee until present fund is exhausted.

(p) Pennsylvania: $10 returned on failure to qualify. No reciprocity.

(q) Tennessee: 50 per cent returned on failure to qualify.

(r) Utah: Fixed by department of registration.

(s) Virginia: $5 returned on failure to qualify.

(t) Wisconsin: $5 every 2 years.

(u) Wyoming: Fee not returned on failure to qualify. Renewal fee $5 every 2 years.

(v) Model Law: In states where registrants are few, the annual renewal fee may be $5, but in larger states $1 may be sufficient.

* Arizona: "If application is denied, the registration fee shall be returned, less the cost, as determined by the Board, of considering the application."

TABLE 4 REGISTRATION REQUIREMENTS

(1)	(2)	(3)	(4) Experience (years)	(5) Experience (years)
	Age	Citizenship	Non-graduates	Graduates of accredited engg school
Alabama	..	.....	8	4
Arizona	25	.....	8	4
Arkansas	21	.....	4	2
California	25	.....	6	2
Colorado	25	.....	7	3
Connecticut	..	.....	8	4 (a)
Florida	21	.....	3	0
Idaho	21	.....	6	0
Illinois	21	.....	6	4
Indiana	..	U. S. or Can.	8	4
Iowa	25	.....	6	2
Kansas	25	.....	8 (b)	4 (b)
Louisiana	21	.....	0	0
Maine	35 (c)	.....	8	3
Michigan	21	U. S. (d)	6	2
Minnesota	25	U. S. or Can.	5	4
Mississippi	21	U. S. or Can.	6	1
Nevada	21	U. S.	0	0
New Jersey	21	U. S.	6	4
New Mexico	35 (e)	.....	8	4
New York	25	U S. or declaration	8	4
North Carolina	21	U. S.	10 (f)	4 (f)
Ohio	..	.....	8	4
Oklahoma	25	.....	8	3 (g)
Oregon	21	.....	6	2
Pennsylvania	21	U. S. or Can. (h)	10	2
South Carolina	21	U. S.	4	0
South Dakota	21	U. S.	6	2
Tennessee	..	.....	4	0
Utah	..	.....	8	4
Virginia	21	U. S.	4	0
Washington	..	State (i)	7	3
West Virginia	21	.....	7	3
Wisconsin	..	.....	7	3
Wyoming	25	U. S.	8	4
Model Law	..	.....	8	4

NOTES TO ACCOMPANY TABLE 4

(*a*) Connecticut: "Or passing an examination in engineering work of a character satisfactory to the board."

(*b*) Kansas: "The character, experience and training of the applicant shall in no case be less than that required for corporate membership in the A.S.C.E., A.S.M.E., A.I.E.E., and similar national engineering societies," interpreted as requiring 8 years practical experience of a character satisfactory to the Board, for which credit is given for time spent in an accredited engineering school. In effect this interpretation makes full distinction between graduates and nongraduates.

(*c*) Maine: Minimum age 35 years for registrants under the grandfather clause. No age requirement for regular registrants.

(*d*) Michigan: Residents of foreign countries may be registered "to engage as principals" in the practice of engineering "when they are recognized as consulting specialists in some branch of their profession and have had at least 10 years experience as such" or under conditions of reciprocity.

(*e*) New Mexico: Same as Maine.

(*f*) North Carolina: By a ruling of the Board. The minimum specified in the law is 5 years for nongraduates and graduation from an accredited school is prima-facie evidence of qualification.

(*g*) Oklahoma: For graduates of engineering schools "of recognized high standing satisfactory to the board."

(*h*) Pennsylvania: Citizens of foreign countries, who have practiced for more than 10 years, may be registered "at the discretion of the board."

(*i*) Washington: A registrant must be "a resident of this state or of a state, territory, or foreign country in which the requirements for the practice of the profession of engineering and/or land surveying are of a standard substantially equivalent to those of this act, and the state, territory, or country of his residence is authorized to grant equivalent reciprocal registration rights and privileges to registrants under this act."

TABLE 5 EXAMINATIONS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Type of examination				
	Personal appearance required	Examination required	Written	Oral	Written and oral	No. of days for exam.	Exam. required of college graduate
Alabama	...	...	..	..	..	...	...
Arizona	No*	No*	..	..	√	3	No*
Arkansas	Yes	Yes	..	..	√	1	Yes
California	Yes	Yes (*a*)	..	..	√	4 (*a*)	(*a*)
Colorado	No (*b*)	No (*b*)	√	..	..	1	Yes
Connecticut	...	...	..	..	..	...	...
Florida	No (*c*)	No (*c*)	√	..	..	3	Yes (*c*)
Idaho	Yes	No (*d*)	√	..	..	2	Yes
Illinois	Yes	Yes	√ (*e*)	..	..	3 (*e*)	Yes
Indiana	No (*f*)	No (*f*)	√	..	..	1	(*f*)
Iowa	No (*g*)	No (*g*)	√ (*g*)	..	√	2	Yes
Kansas	Yes (*b*)	Yes (*b*)	..	..	√	2½	No (*b*)
Louisiana	No†	No†	√	..	..	2	No†
Maine	...	...	..	..	..	...	...
Michigan	No (*i*)	No	√	..	..	3	Yes
Minnesota	No (*j*)	No (*j*)	(*j*)	..	..	...	(*j*)
Mississippi	...	...	..	..	..	...	...
Nevada	...	...	..	..	..	...	...
New Jersey	Yes	No (*k*)	√	..	..	1	Yes (*k*)
New Mexico	...	...	..	..	..	...	...
New York	No (*l*)	No (*l*)	√	..	.	3	Yes
North Carolina	No	No	√	..	..	2	No (*m*)
Ohio	No	No	...	..	√	...	No
Oklahoma	...	...	..	..	..	...	...
Oregon	Yes (*n*)	Yes (*n*)	..	..	√	1½	Yes
Pennsylvania	No (*o*)	No (*o*)	..	..	√	1	No (*o*)
South Carolina	Yes (*p*)	Yes (*p*)	..	√	..	1	Yes
South Dakota	Yes (*q*)	Yes	√	..	..	12 hr	Yes
Tennessee	...	...	..	..	..	...	...
Utah	...	...	..	..	..	...	...
Virginia	No (*r*)	No (*r*)	√	..	.	3	Yes
Washington	...	...	..	..	..	...	...
West Virginia	No (*s*)	No (*s*)	..	√	..	1 hr	No
Wisconsin	No (*t*)	No (*t*)	..	..	..	16 hr	No (*t*)
Wyoming	No (*u*)	No (*u*)	√	..	..	2	Yes

NOTES TO ACCOMPANY TABLE 5

(*a*) California: An applicant submitting satisfactory evidence that he has, through professional accomplishments attained an outstanding reputation as a civil engineer may, in the discretion of the Board, be excused from the written examination. Two days in fundamentals of civil engineering, two days in civil engineering design and construction. Graduates from accredited schools excused from examination in fundamentals of civil engineering.

(*b*) Colorado: Personal appearance required only in exceptional cases and usually at the request of applicant. Examination required only when the Board is in doubt as to qualifications.

(*c*) Florida: The Board is considering having most applicants appear—probably all who take written examination. Applicants of outstanding training and ability often registered without examination. Examination required of graduates unless they have the required number of years of experience, in addition to graduation.

(*d*) Idaho: Persons registered in another state, whose minimum requirements are no less than those of Idaho, may be registered without examination.

(*e*) Illinois: Applicants of more than 10 years experience may take an oral examination. Applicants from other states who hold registration as professional engineers, are given oral examination. For others, one day oral, and two days written.

(*f*) Indiana: Personal appearance and examination not required when the technical and professional experience set out in the application, together with the supporting evidence, is sufficient to convince the Board that the applicant is competent to be placed in responsible charge of important engineering work. Examinations for graduates optional with the Board, depending upon their professional experience and other qualifications.

(*g*) Iowa: Personal appearance and examination not required of registered engineers from other states who have already been examined elsewhere and have reciprocal registration with suitable references. Examinations mainly written.

(*b*) Kansas: Personal appearance and examination required unless waived by the Board, which is customarily done by letter ballot in the cases of graduate engineers of unquestionable character and experience. Written examination of graduates is usually waived.

(*i*) Michigan: Only in cases of doubt.

(*j*) Minnesota: No personal appearance or examination when conclusive evidence is shown in application. Graduates not examined for educational qualifications but for evidence of practical experience.

(*k*) New Jersey: Exemptions: (1) Applicants who are graduates of school or college approved by the Board (photostatic copy of diploma to accompany application); (2) applicants licensed in other states (photostatic copy of certificate); (3) applicants having 10 or more years of qualifying experience. Examination fee of $5 required of all applicants who are required to take the examination.

(*l*) New York: Either the Board or the applicant may request personal interview. In the case of applicant who is qualified as to age, character and citizenship, and is possessed of long-established and recognized standing in the engineering profession, who has practiced lawfully for more than 15 years, a license may be granted without written examination.

(*m*) North Carolina: Graduation from accredited school is prima-facie evidence according to the law. By ruling of the Board, at least four years experience is required for consideration of such applicant.

(*n*) Oregon: Except through reciprocity.

(*o*) Pennsylvania: Except in cases of doubt as to qualifications.

(*p*) South Carolina: Except for applicants under reciprocity clause, with qualifications satisfactory to the Board.

(*q*) South Dakota: Reciprocal registrants do not have to appear.

(*r*) Virginia: Persons who can satisfy the Board that they were

NOTES TO ACCOMPANY TABLE 5 (*Continued*)

practicing in responsible charge of work, either design or construction, not less than six years prior to 1924, may be registered without examination, and are not required to appear before the Board in some cases.

(*s*) West Virginia: Personal appearance and examination required only in cases of doubt.

(*t*) Wisconsin: Personal appearance not required when applicant possesses certificate by the National Bureau of Registration. Graduates with three years subsequent experience may be registered without examination.

(*u*) Wyoming: When it is inconvenient and causes the applicant unnecessary expense and loss of time to appear before any member of the Board, arrangements are made to allow the applicant to take the examination before some responsible person. No examination required when experience, education, etc., does not necessitate.

* Arizona: "All applicants must submit sufficient data as to education, experience and employment, verified by the testimony of references, and supported by examples of work done. Lacking such satisfactory material after the same has been surveyed and inspected by the Board, an applicant may be "held for examination." Every applicant *must* submit a transcript of his technical school record, and additional evidence of application to actual practice (or responsible connection with work). Examinations have been required of graduates whose work has been in other lines than that for which the technical school prepared them.

† Louisiana: "Graduates of schools on this Board's list of approved institutions are not required to appear or take examination. Those who are not graduates must appear before a representative of the Board and take the written examination."

TABLE 6 PENALTIES FOR VIOLATIONS

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Fines		Imprisonment, months		No. of prosecutions	No. of revocations
	Min	Max	Min	Max		
Alabama	$100	$500	...	3	..	..
Arizona	$100	$500	...	6	0	0
Arkansas	$ 10	$200 (*a*)	...	3	0	0
California	...	$500	...	3	24	25
Colorado	$100	$500	...	3	0	0
Connecticut	...	$500	...	3	..	..
Florida	(*b*)	...	...	...	10	2
Idaho	(*c*)	...	...	...	0	0
Illinois	$ 25	$200	None	None	0	0
Indiana	$100	$500	...	3	4	2
Iowa	$100	$500	...	3	0	0
Kansas	$100	$500	...	3	0	0
Louisiana	$100	$500	30 days	90 days	0	0
Maine	$100	$500	...	3	..	..
Michigan	...	$100 (*d*)	...	(*d*)	1	1
Minnesota	(*e*)	...	...	...	0	0
Mississippi	$100	$500	...	3	..	..
Nevada	$ 25 (*f*)	$100 (*f*)	...	...	..	..
New Jersey	$100	$500	...	3	0	0
New Mexico	$100	$500	...	3	..	...
New York	$100	$500	...	12	4	1
North Carolina	$100	...	3	3	0	0
Ohio	$100	$500	None	None	0	0
Oklahoma	$100	$500	...	90 days	..	...
Oregon	$ 25	$500	...	6	1	1
Pennsylvania	$100	$500	...	3	0	1
South Carolina	...	$500	...	3	0	0
South Dakota	...	$500 (*g*)	...	30 days	1	1
Tennessee	$100 (*b*)	$500	...	3	..	...
Utah	...	...	...	...	..	...
Virginia	$100	$500	None	None	0	0
Washington	(*i*)	...	...	...	..	...
West Virginia	$100	$500	...	3	0	0
Wisconsin	$100	$500	...	3	0	0
Wyoming	$100	$500	...	3	1	0
Model Law	$100	$500	...	3	..	...

NOTES TO ACCOMPANY TABLE 6

(*a*) Arkansas: One hundred dollars maximum for illegal use of seal.

(*b*) Florida: Misdemeanor; penalty not stated in registration act.

(*c*) Idaho: Illegal practice or offer to practice a misdemeanor; giving false or forged evidence in application, or false impersonation of a registrant, a felony.

(*d*) Michigan: Five hundred dollars and/or one year for second offense.

(*e*) Minnesota: Misdemeanor; penalty not stated in registration act.

(*f*) Nevada: Fifty dollars to five hundred dollars for second offense.

(*g*) South Dakota: One thousand dollars and/or three months for second offense.

(*h*) Tennessee: Illegal practice or offer to practice, $10 to $50, each day constituting a separate offense.

(*i*) Washington: Misdemeanor; penalty not stated in registration act.

TABLE 7 REGISTRATION STATISTICS

(1)	(2)	(3)	(4)	(5)	(6)
	Population of state, 1930 census	Professional engineers, 1930 census	Engineering society membership	Total no. registered to July 1, 1935	No. in good standing July 1, 1935
Alabama	2,646,248	2,155	251	....	....
Arizona	435,573	1,256	248	732	286
Arkansas	1,854,482	948	102	218	218
California	5,677,251	18,033	3,914	5,290	4,346
Colorado	1,035,791	1,456	689	500+	500
Connecticut	1,606,903	3,476	985	....	....
Florida	1,468,211	1,573	302	1,412	649
Idaho	445,032	341	144	361	174
Illinois	7,630,654	18,010	2,687	1,449	852
Indiana	3,238,503	1,666	589	2,471	1,492
Iowa	2,470,939	1,494	312	1,731	1,220
Kansas	1,880,999	1,231	284	266	260
Louisiana	2,101,593	1,276	329	1,002	502
Maine	797,423	911	143	....	....
Michigan	4,842,325	10,566	1,171	1,760	1,186
Minnesota	2,563,953	1,818	469	1,173	968
Mississippi	2,009,821	641	81	....	....
Nevada	91,058	395	114	....	....
New Jersey	4,041,334	16,512	2,386	3,303	2,263
New Mexico	423,317	513	111	....	....
New York	12,588,066	37,785	10,527	13,640	10,358
North Carolina	3,170,276	1,208	307	1,001	335
Ohio	6,646,697	14,492	2,216	3,200	3,200
Oklahoma	2,396,040	2,363	391	....	....
Oregon	953,786	1,395	338	1,720	784
Pennsylvania	9,631,350	19,221	4,711	5,436	3,507
South Carolina	1,738,765	636	118	411	143
South Dakota	692,849	224	84	376	225
Tennessee	2,616,556	1,559	437	....	....
Utah	507,847	1,149	269	....	....
Virginia	2,421,851	1,440	440	583	237
Washington	1,563,396	4,268	693	....	....
West Virginia	1,729,205	1,292	354	721	489
Wisconsin	2,939,006	2,909	695	678	656
Wyoming	225,565	244	68	219	219
Total	97,082,665	174,456	37,129	(49,653)	(35,069)

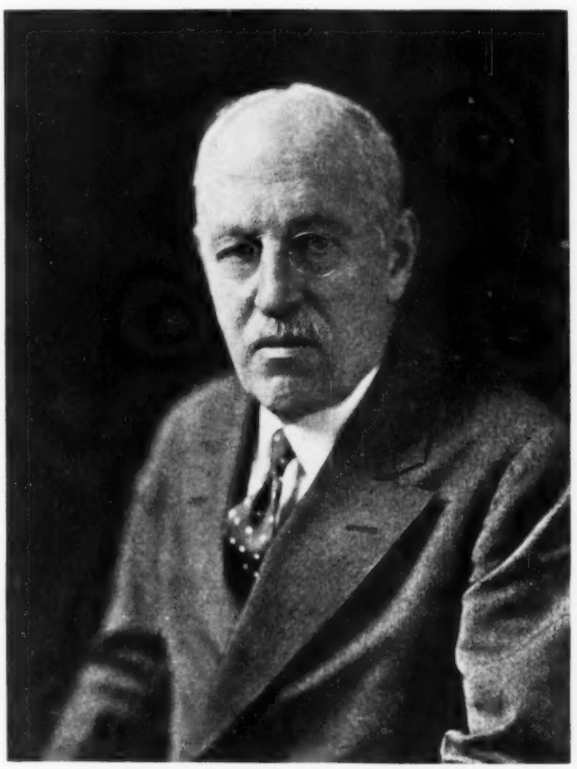
WILLIAM WALLACE ATTERBURY

1866–1935

MANY technically trained mechanical engineers, after extensive experience in railroad service, have become associated with allied industries and have advanced to high and important executive positions. Very few, however, have become chief executives of railroads. The late William Wallace Atterbury, an honorary member of The American Society of Mechanical Engineers, is the most outstanding example of such advancement.

What qualities, beyond that of a technical training, equipped him to become one of the great railroad executives of his generation—not alone as the chief executive of one of the world's largest and most important railway systems in an exceedingly difficult period in American railroad development, but also as director general of transportation of the American Expeditionary Forces in France, a position in which he rendered invaluable service during the World War?

A satisfactory answer to this question would require an extended biographical treatise, comparable with those which have been published by The American Society of Mechanical Engineers in recent years, and it is sincerely to be hoped that ways and means may be found for publishing such a biography. I shall attempt here to designate only a few of the more prominent characterisics which accounted for General Atterbury's unusual success.



WILLIAM WALLACE ATTERBURY

William Wallace Atterbury was born at New Albany, Ind., January 31, 1866, and spent his early life in Detroit, Mich. He was graduated from Yale University in 1886 and shortly thereafter, on October 11, became an apprentice on the Pennsylvania Railroad, at Altoona, Pa. An apprenticeship in those days was no sinecure; the pay was five, seven, and nine cents an hour for the first three years. The working hours were 7:00 a.m. to 12 noon; 12:30 p.m. to 6:00 p.m., except on Saturday, when the shops shut down at 5:00 p.m. When business was rushing the shops were also open three evenings a week, from 7:00 p.m. to 1:00 a.m. Hard work; but happy days, according to the reports of Atterbury's associates in those early days.

James Millikan, who preceded Atterbury as an apprentice at Altoona by a few months, looked him up shortly after he reported and asked him where he lived. "I am rooming with Old Tom" (the company night policeman, and a fine, loyal fellow, who weighed more than 300 lb), said Atterbury. "He sleeps in the bed in the daytime and I sleep there at night." And then, according to Millikan, "he threw back his head and laughed that gay, contagious laugh for which he was noted all his life—the laugh that brought him many friends and carried him over many difficulties."

At the end of his apprenticeship in 1889, Atterbury was sent to Philadelphia and then to Derby, on the Pennsylvania division, as assistant road foreman of engines. There he came under J. K. Russell, a sterling, loyal, practical, old-time railroader—a just and stern disciplinarian. Atterbury, in later life when dealing with difficult labor problems, frequently acknowledged his indebtedness to Russell, who taught him the true value of organization and discipline, with fairness at all times, justice and discipline being tempered with mercy.

Atterbury served as assistant road foreman of engines on other divisions and in 1892 was promoted to assistant engineer of motive power of the Pennsylvania's Northwest System. In 1893 he was made master mechanic at Fort Wayne, Ind. Here his vigorous and successful handling of the strike of enginemen and trainmen in 1894 brought his abilities as an executive to the attention of those in authority, and on October 26, 1896, he was made superintendent of motive power of the Pennsylvania Lines East of Pittsburgh and Erie. Young college graduates, serving as special apprentices at Altoona during these years, recall with appreciation and enthusiasm the invitations for Sunday dinners in the Atterbury home. He was advanced to general superintendent of motive power October 1, 1901.

Always of an inquiring mind and ambitious to get ahead, Atterbury took advantage of every opportunity to study operating methods and practices. He assumed all the authority his superiors or the operating officers with whom he was associated would delegate or entrust to him. The knowledge and experience thus gained proved a valuable asset during the boom in 1902, when the railroad was swamped with business and encountered one of its most serious freight congestions. Atterbury, although a mechanical-department officer and only 37 years of age, showed such a clear understanding of the complicated factors involved that President Cassatt, to the amazement of his associates, advanced him on January 1, 1903, to the general managership of the Pennsylvania Lines East of Pittsburgh and Erie.

The president's judgment was quickly vindicated, for Atterbury promptly unraveled the traffic snarl and got things running smoothly. On March 24, 1909, he was made fifth vice-president in charge of transportation. A change in organization was effected March 3, 1911, and he was elected fourth

vice-president and also a director of the company. The numerical designation of vice-presidents was discontinued May 8, 1912, and his title was changed to vice-president in charge of operation. Then followed eventful years.

As head of the American Railway Association, to whose presidency he was elected May 17, 1916, Atterbury rendered invaluable service in the transportation of troops and war supplies to the Mexican border, and of supplies to the eastern seaboard. It is not strange, therefore, that when General Pershing cabled in July, 1917, "Successful handling our railroad lines so important that ablest man in country should be selected," Atterbury was sent to France and made director general of transportation for the American Expeditionary Forces. It was a stupendous task, in a foreign land and under the stress of the Great War, to organize to meet the United States transportation requirements in France and to harmonize the facilities and efforts with those of our Allies. He sailed for Europe in August, 1917, and was commissioned Brigadier-General of the United States Army, October 5, 1917. He returned to America May 31, 1919, to resume his duties on the Pennsylvania Railroad.

That his efforts in the World War were eminently satisfactory is indicated by the many decorations which he received, including the Distinguished Service Medal from the United States; the Legion of Honor, Rank of Commander, from France; Companion of the Most Honorable Order of the Bath, from Great Britain; Commander of the Order of the Crown, from Belgium; Royal Order of the White Eagle, from Serbia; and Grand Officer of the Order of the Crown, from Rumania.

Postwar conditions on the railroads, with the trying problems of rehabilitation and readjustment and severe labor difficulties, were hardly less serious and difficult than those involved in the War, and General Atterbury, as head of the operating department of the Pennsylvania Railroad, exercised an influence and leadership which had a profound effect upon the progress and improvement of the American railway system. With courage and directness he approached the problem of discovering a successful method of settling differences arising between the management and the employees. This task on a railroad, with its different types of labor organizations, including the brotherhoods, unions affiliated with the American Federation of Labor, and other types, is much more involved and difficult than in other industries. The situation is further complicated by the fact that governmental agencies enter the situation more actively, the railroads being public-service institutions.

General Atterbury's success in dealing with his co-workers may be gaged by the following statement of one of the labor leaders. "I cannot help but feel that had General Atterbury the choice, he would rather be known to posterity as the originator of the plan which brought permanent peace and goodwill to the Pennsylvania Railroad and its employees, than as the great railroad executive that he was."

Shrewd labor leaders, sitting across the table from representatives of management, appraise their opponents with keen and ruthless discrimination. Here is the appraisal of a labor leader who had contacts with General Atterbury over a quarter of a century, or more. "Those phases of General Atterbury's personality with which I have been most deeply impressed were his unconscious naturalness, his directness of approach to the subject under consideration, his rigid adherence to his promises or decisions once they were given (there was no splitting of hairs with General Atterbury when it came to applying any agreement or understanding he had made with the Pennsylvania employees), and his consideration of matters, not on the basis that they must be settled in a certain manner because he, the one in authority, willed it so, but on the basis of what should be done, giving proper regard to the rights and interests of all concerned."

The public at large frequently has peculiar conceptions of the lives of men of prominence. The real characters of these men are best known and understood by their intimates who work with them "behind the scenes."

"A notable trait of the General," said one of his intimate co-workers, both on the Pennsylvania Railroad and in France, "was his courage, poise, and patience in the face of difficulties."

"In any matter of moment," said this same associate, "Once he reached a definite conclusion as to the course which should be pursued, he proceeded accordingly and calmly awaited developments. His conclusions were reached after careful consideration of advice and suggestions, which he at all times welcomed from any source. Whenever he was confronted with unusual difficulties he had a way of doing all he could in the circumstances, then relaxing, and tackling the next day's work in the light of conditions as they unfolded.

"Incidentally, the ability to throw off cares and relax was a prominent attribute of the General. He was a splendid example of the type of executive who knows how to blend work and recreation and who functions in an orderly fashion without stress or strain. Golf, cards, and light reading were his favorite forms of recreation."

General Atterbury was elected vice-president on November 15, 1924, and advanced to the presidency October 1, 1925. One of his last great achievements is summed up in the following paragraph, which is taken from a minute adopted by the board of directors of the Pennsylvania Railroad Company at its meeting on April 24, 1935, when, because of ill health, he declined to accept nomination for re-election as president.

"His courage in the face of obstacles is well exemplified by his prosecution of the work of electrifying the lines of the company between New York and Washington. Begun in 1928, the work was halted by the difficulty of financing, brought about by the worldwide depression. Upon the offer of the Government to advance funds, Mr. Atterbury did not hesitate; he accepted the offer and pushed the work to a conclusion, so that the lines were open for operation in February of this year."

It was at his suggestion, also, that the Association of American Railroads was devised to promote and improve railroad service in the public interest and to maintain the integrity and credit of the industry. This association, organized October 12, 1934, makes it possible for the railroads to present a united front in problems which face the industry as a whole.

General Atterbury was among the first of those leaders who have a vision of a coordinated transportation system for this country—a system in which each type of transportation will take that place for which it is best suited on a sound economic basis, and in the public interest. Although, from the standpoint of practical accomplishment, comparatively little has been done up to the present time, General Atterbury helped to lay the foundation upon which substantial progress can be confidently anticipated in the years immediately before us.

General Atterbury died October 20, 1935, following a long illness. He was a member of many learned societies. Honorary membership in The American Society of Mechanical Engineers was conferred upon him at a memorable meeting in Altoona, Pa., in 1925. He was given the honorary degree of Master of Arts by Yale University in 1911. Several universities conferred upon him the degree of Doctor of Laws, including the University of Pennsylvania in 1919, Yale University in 1925, Villanova College in 1927, and Temple University in 1929. Pennsylvania Military College gave him the degree of Doctor of Engineering in 1932.—ROY V. WRIGHT.

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Automatic Power and Mixture Control for Aircraft Engines

THE basic idea of accomplishing both a power limitation and a control of the mixture with one unit was evolved by the late Thorp Hiscock. He proposed, by throttling the air entering the carburetor, to maintain the density of air entering the venturis equivalent to that at an altitude of 7000 ft. Thus the carburetor would virtually be held at 7000 ft and would deliver, even though the airplane might be at sea level, a mixture of the same fuel-air ratio that it would normally deliver at 7000 ft.

Details of the development of the automatic-power and mixture-control unit are given, together with descriptions of tests made and statements of results obtained.

In conclusion, it is stated that, from the reports available on general fuel consumptions, it is apparent that some method of control is desirable. Further, that it is also highly desirable from a standpoint of engine reliability and durability that a means of controlling the horsepower output of supercharged engines as well as the fuel consumption be provided. The device described provides both features, with certain limitations. (Guy E. Beardsley, Jr., Project engineer, Pratt & Whitney Aircraft Co., in *S.A.E. Journal*, vol. 39, no. 2, August, 1935, pp. 301–306, illustrated)

Airplane Carriers

FROM data presented in this article it would appear that from a marine point of view this type of vessel is not highly efficient.

Great length and width are required for the flight deck, so that it may meet efficiently its varied requirements. This involves a large weight carried high above the vessel's hull proper, so as to provide ample head room in the hangar usually located immediately below. In order to prevent excessive heel due to beam winds, and also to reduce list when the ship is damaged, comparatively large values of the metacentric height are essential. However, if "sea kindliness" is to be secured, there is a limit beyond which one cannot wisely go in this direction.

The airplane-carrier's hull is usually of generous depth, so as to house boilers, machinery, gasoline tanks, fuel oil, stores, airplane wings, shops, and quarters for the personnel. It results that the center of gravity of the ship is usually high, being perhaps 50 or 60 per cent of the ship's designed draft above her designed waterline. Then, in order to secure the value of metacentric height desired, it is usually necessary to resort to great beam. This, combined with the great length necessitated by the flight-deck requirements, all on a limited displacement, is almost certain to result in a scant draft. So one arrives at the characteristic proportions of a typical airplane carrier. Such proportions produce reasonable bending moments in ships with underwater and side-belt protection, but where such features are absent the bending moments may become large.

Carrying the uptakes to a fixed stack standing well to one side of the flight deck and of height sufficient so that a pilot may normally obtain a clear view of the flight deck from below the smoke, preparatory to landing, is a generally satisfactory arrangement. Also this method simplifies the engineering problems and is relatively economical of weight. However, once a fixed structure rising above the flight deck is accepted, additions are immediately constructed around or in connection with it. The result is an "island" which provides not only for stacks but bridges, navigation and fire-control instruments and stations, and air-control structures.

While, for the purposes just noted, the island is perhaps an ideal solution, its construction involves great weight placed high and at a considerable distance transversely from the centerline of the ship. Ordinarily, it is not practicable to locate permanent weights so as to provide an equal heeling moment, but in the opposite direction to that of the island. If this cannot be done, the operating personnel is faced with a never-ending problem in transverse balance, a problem which must be continually solved by the adjusting of liquid weights in the form of the oil and water ballast.

There are other difficult problems briefly referred to in the article. (J. M. Bates, *Marine Engineering*, vol. 40, no. 9, September, 1935, pp. 334–337, 2 figs.)

APPLIED MECHANICS

Stresses in Overstrained Materials

THE subject of stresses in overstrained materials is becoming increasingly important. Thus, the practice of welding leaves the problem of plastic overstrain more prominently in the position of the limiting factor in design, in many cases of economic importance. In such circumstances it appears desirable that current methods of design should be adapted to recognize the danger of plastic strain in a more definite and formal manner, so that the margin of safety of a structure under its working loads may be judged by direct comparison with the overloads that would be required definitely to produce undue plastic overstrain in the ductile metal.

The investigations carried out by the committee (of the British Association) confirm the view that has long been held by many engineers, viz., that the elastic limit in the case of mild or moderately high-tensile structural steel is unsuitable for use as a reference value for purposes of design. The value depends unduly upon the method of testing adopted; and when special precautions are observed to insure that scientific accuracy is attained, the value is much higher than is generally believed, and misleading for general application.

The yield point of the material is considered to afford a more reliable basis for design in cases where plastic overstrain is regarded as the limiting factor; but the yield point also—as now generally measured in accordance with current standard specifications—is open to the objection that its value also varies according to the method of testing and probably with the rate of application of load in the tensile test.

The so-called "lower yield point" has been studied with particular attention and is considered to afford the most

satisfactory and reliable basis for the comparison of structural steels and for the design of structures in which plastic overstrain must be limited; and it is recommended that a specification of the lower yield point should be adopted for the use of those who may desire to employ it. At present, although the lower yield point is already used by many who have experience of its advantages, no specification for its measurement appears among the British Standard Specifications for yield point.

The list of advantages of the use of lower yield point as a basis for the comparison of different structural steels is given in the original paper. (Report of the committee appointed by Section G, British Association to consider stresses in overstrained materials, presented at the Norwich meeting, Sept. 5, 1935, abstracted through *Engineering*, vol. 140, no. 3635, Sept. 13, 1935, pp. 291–292)

ENGINEERING MATERIALS

Relationships in Cast-Iron Test Results

THE suggestion that cast iron is unreliable is to some extent justified when it is compared with a simple material like steel as, owing to the number of variable factors which operate in the production of iron castings, it is difficult to duplicate results exactly. However, if the extent of the variations can be determined, the resulting knowledge narrows the uncertainty to a known range; confidence on the part of the designer is promoted and the large safety factors, generally considered necessary when using cast iron, may be modified.

There are a number of popular ideas regarding cast iron leading to the idea of unreliability which, it was felt, justified examination first to find if they were true, and, if so, to what extent they operated in the mixtures under the author's control. Several investigations have been carried out on these and other points, mainly in the direction of establishing relationships, with a view to finding out the nature of any variables.

The most common test applied to cast iron is the transverse test, but the engineer, as a rule, prefers to consider tensile strength as a basis for design. It would be advisable, therefore, to have a ratio established between transverse and tensile-strength tests. Such a relationship requires that both properties be in the same terms—pounds or tons per square inch. This is usual for tensile-strength tests, but the load in transverse requires conversion to the modulus of rupture by a formula which takes into consideration the shape, size, and span of the test bar. It is therefore essential that the bar be measured accurately, as a slight variation in size, even when using the same pattern, will cause comparatively wide differences in breaking loads.

When the 2-in. by 1-in. bar was used, it was usual to allow 1 cwt per $^1/_{32}$ in., which was fairly close for small differences when the breaking load was from 30 to 35 cwt. Using the M bars for grade-A iron, 0.025 in. will affect the breaking load about 100 lb, or 1.2 tons modulus of rupture (5 per cent error), and with an iron of 16 tons tensile about 160 lb, or 1.8 tons (6 per cent error), so that for routine testing, when using the same size of bar for comparing different mixtures, the corrected breaking load is necessary, and the modulus of rupture must be determined to compare the results of bars of different shapes. The B.C.I.R.A. (British Cast Iron Research Association) recommendation (see J. G. Pearce, *Foundry Trade Journal*, Sept. 27, 1938, p. 219) that modulus of rupture be used for reporting transverse strength is strongly supported, and this method is used by the author.

It is an advantage to have a chart with the correction factors for most of the variations of standard bars, and this is given in Table 2 in the original article, together with the formulas and factors for calculating the modulus of rupture. Columns 2, 5, and 8 give the factors for calculating breaking load to correct size, and columns 3, 6, and 9 the factors for calculating modulus of rupture direct from the breaking load of bars of incorrect sizes.

From an examination of a series of tests the following conclusions regarding transverse and tensile relationship are reached by the author. The ratio falls with increasing strength from 2.3 at 10 tons tensile to 1.6 or less at over 20 tons tensile, but is not constant for any particular range of strength within closer limits than ±8 per cent, except when produced under closely controlled conditions, when, from a mixture of predetermined strength, a normal transverse result will generally indicate a normal tensile strength. Machined transverse bars are higher in strength than bars tested "as cast," thus giving higher ratios—a difference which increases with increasing strength.

On the whole, it is felt that for irons in which strength is an important feature, the transverse test is a useful guide for routine tests, but for all other purposes the determination of tensile strength is preferable to estimation from transverse strength, particularly as engineers think of strength in terms of tensile, and therefore by this method will more readily appreciate the improved properties of cast iron and the high strengths now available. Moreover, tensile will probably prove the more suitable means of classification when the high-strength irons are included in a standard specification.

The author also discusses the effect of surface condition on the transverse result relation between tops and bottoms of bars, effect of span on modulus of rupture, relationship between different sizes of test bars, and effect of section size on strength. A short bibliography is appended. (G. L. Harbach in *The Engineer*, vol. 160, no. 4156, Sept. 6, 1935, pp. 251–252)

FOUNDRY

Die Casting Under Pressure

A GENERAL article describing the process and the various machines. The Polak machine is well known in the United States. The Eckert machine is of the vertical type and uses an upper hydraulic cylinder working from the top downward. It is mounted on four columns and carries at the bottom of its piston a plate to which is attached the movable part of the mold together with the ejection mechanism. The columns are attached to the lower part of the structure, which comprises the injection hydraulic cylinder and carries the fine part of the mold, the imprint of which is directly above the injection or rather the compression cylinder. (There is no real injection in this machine.) The compression chamber consists of the stationary mold structure and the space comprised between the latter and the piston in its lower position. After the mold has been closed, this being done on a horizontal joint, the compression piston in going up forces a thick-flowing alloy to fill up the cavity.

In the Thieslack machine the compression cylinder is horizontal and the mold has a horizontal joint located in the axis of the piston. The two half molds are fixed on two blocks—one stationary, and the other movable, having the same joint as the mold proper.

One of the big problems in the design of this kind of machinery is reducing to a minimum the consumption of water under pressure, which is expensive. The working pressures vary with the alloys that have to be cast. In the majority of cases with aluminum alloys the pressure is from 200 to 230 kg per sq cm and with copper alloys from 500 to 600 kg.

As a rule where the foundry has a certain number of machines the melting of the alloy is done in a single furnace in order partly to insure economic welding and also homogeneity of the alloy. In addition to this main furnace a small individual furnace is provided for each machine. Its purpose is to maintain the alloy at a suitable temperature. These little furnaces are often mounted on wheels.

The maintenance of a uniform temperature of the alloy at the time when it is introduced into the compression chamber is important and the author recommends the use of control apparatus and apparatus for measuring the temperature of the middle of the ladle at the instant when the metal is poured into the machine. It is also important for the success of the process that the compression chamber and mold be maintained during the entire course of operation at as constant a temperature as possible. The author enumerates the alloys which can be used in the die pressure casting. They are brasses, aluminum bronzes with or without the addition of titanium, Tombasil alloy (80 to 82 per cent copper, 4 to 5 per cent silicon, and the rest zinc), silver alloys, etc. (G. d'Ardigny in *La Revue de Fonderie Moderne*, vol. 29, May 25, 1935, pp. 163–164)

FUELS AND FIRING

Propagation of a Zone of Combustion in Powdered Coal

WORK on the propagation of a zone of combustion in powdered coal has been undertaken in the belief that the measurement of the rate might provide a rapid and simple routine test for differentiating coals according to their tendencies to spontaneous heating.

Among other things the author comes to the conclusion that the introduction of a shape factor for irregularly shaped particles of coal, while providing an increased accuracy, is not justified, as microscopic examination showed that the shapes of the particles of the coals were sufficiently similar for the effect of the shape factor on the determination of specific surface to be neglected.

It was shown that the volume of oxygen absorbed by the coals increased with increasing specific surface, but the absorption of oxygen was not directly proportional to the specific surface of the coal dusts.

The rate of propagation of the zone of combustion increased with increasing fineness, but a degree of fineness was reached beyond which further subdivision of the particles did not increase the rate of combustion. Experiments indicated that the effect of the larger particles in interfering with the flow of heat between the finer and more reactive particles was a more important factor in causing this optimum rate of combustion than the relatively slower rate of oxidation and consequent decreased production of heat by the larger particles.

In determining the relative ease of oxidation of coals, it is necessary to standardize the fineness of the dusts. Variations in fineness are minimized by employing closely sized fractions. In the present experiments, however, dust passing through 200 mesh is used and, owing to the difference in the time of propagation with different periods of grinding and to variation in the "grindability" of coals, it is not possible to compare their oxidizabilities by the time of propagation of a zone of combustion through a sample obtained by a standard period of grinding. It has been found, however, that after a certain period of grinding, the time of combustion assumes a value which is not altered by further subdivision of the particles.

From these results, it appears to be possible to measure the relative tendencies of coals to oxidize by the limiting time of propagation of a zone of combustion along the standard "train" of coal dust sieved to pass through a 200-mesh I.M.M. sieve. It is recognized, however, that the difference (2 min) in the time of propagation between the least and the most oxidizable coal is not as great as might be expected from their ultimate analyses, the percentages of oxygen in these two coals being 5.9 and 11.9 per cent, and the percentages of carbon being 87.3 and 80.7 per cent, respectively. (H. E. Newall, *Fuel in Science and Practice*, vol. 14, no. 6, June, 1935, pp. 160–167, 3 figs.)

Capillarity of Coal

VARIOUS investigations relating to the drying and dewatering of coal have indicated that there is some fundamental relationship between those properties determining the washability of coals and their capillarity. To establish whether such relationship exists, researches have been carried out by the coal-preparation laboratory of the Gutehoffnungshütte, and are described in detail by P. Nashan in *Glückauf*. These investigations show that such connection does actually exist, and that the capillarity may be regarded as a true characteristic of coals and differs as from one seam and grade of coal to another.

The investigations outlined are merely tentative, as the author is proceeding with this research and proposes to study the relationship between capillarity of coals and their specific gravity, ash content, the composition of the ash, the petrographic composition, the volatile matter, the coking properties, the bitumen content, the grain size, and other important properties. (*The Iron and Coal Trades Review*, vol. 131, no. 3522, August 30, 1935, pp. 322–324)

HEATING

The Velox Hot-Water Boiler

THIS article tells briefly of two plants and in more detail of a third, where this type of boiler has been installed for heating purposes. The illustration showing the layout of the plant is of a character that cannot be reproduced. On the right is the combustion chamber with the burner and retractable ignition coil at the top and the tubular heating elements arranged as a waterwall around the combustion-chamber shell. On the extreme left is the preheater and economizer, and in the center is the supercharging unit. On the left of this unit is the gas turbine driving the axial-flow compressor, and this is coupled through gearing to a variable-speed commutator motor, which is used for starting and regulation. The boilers are put into service, shut down, and regulated by push-button control from the switchboard, and interlocks insure that the operations are carried out in the right sequence. In this particular installation the gas turbine at full load generates about 50 kw more power than is required by the air compressor, and this surplus power is fed back into the system through the motor.

The heat release in this type of boiler reaches a value of 700,000 to 900,000 Btu per cu ft per hr, and the average rate of heat absorption under normal operating conditions amounts to 110,000 Btu per sq ft per hr. As far as fuel economy is concerned, a thermal efficiency of 87 to 89 per cent, based on the gross calorific value of the oil, is obtained at full load, and there is little variation in efficiency over a wide range down to below 25 per cent of maximum capacity.

In the installation at the City University in Rome two oil-fired Velox boilers are used. In view of the comparatively small size of the units it has been possible to build the supercharging unit directly onto the boiler itself. The

air compressor consists of a central standard radial-flow impeller. The gas turbine is of the single-stage impulse type and is connected through gearing to an auxiliary motor. (E. S. Dean, *The Engineer*, vol. 160, no. 4154, Aug. 23, 1935, pp. 203–204, 5 figs. For a description of the Velox steam generator, see MECHANICAL ENGINEERING, August, 1935, pp. 469–478)

HYDRAULIC ENGINEERING

Argonia Hydraulic Rudder-Operating Device

THIS is part of an article dealing with hydraulically operated control apparatus and refers primarily to such apparatus wherein both the generator and motor are of the hydraulic type. It describes a hydraulically operated servo-rudder device claimed to be simple and cheap to install. It is assumed (Fig. 1) that the vessel is already equipped with the rudder wheel 1, chain 3, and manual control 4, 5, and 6; that it has a motor 7 with flywheel 8, and it is to this latter that a hydraulic generator pump 9 driven from the motor by chain and pinion 10, or some other method, is attached. The generator is supplied with liquid from a reservoir 11 and protected by a bypass 12. There is a receiver 13 attached by some such method as a chain 14 to the rudder shaft, a control valve 15, and a valve 16 for switching to manual control.

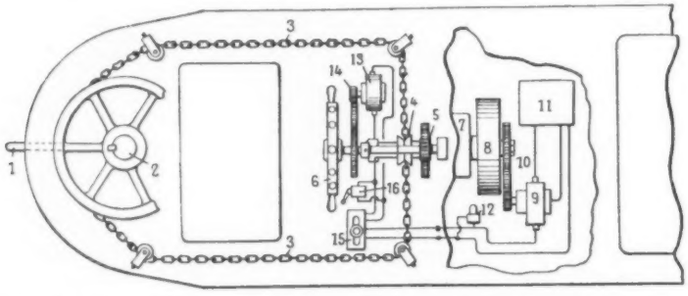


FIG. 1 THE ARGONIA SERVOMOTOR FOR OPERATING A SHIP'S RUDDER
(1 Rudder handle; 2 rudder wheel; 3 chain; 4, 5, and 6 manually operated rudder control; 7 motor; 8 flywheel; 9 generator pump; 10 and 14 gear drive; 11 reservoir; 12 bypass; 13 receiver pump; 15 control valve; 16 valve for shifting to manual operation.)

When pressure is exerted on the lever of valve 15, the vessel is steered in the direction toward which the lever is being forced at a velocity which is a function of the amplitude of the angle through which the lever has been moved. When it is in the median position no action takes place, the rudder being in a position in which it was placed by the preceding maneuver. At such a time the receiver set is hydraulically braked and the generator pump is bypassed, delivering the liquid to the reservoir without pressure. During the maneuver the pressure is a function of the resistance that has to be overcome and varies from 5 to 35 kg per sq m. The rudder wheel 6 turns if an action on 15 is exerted. Means are provided to pass from hydraulic operation to manual and vice versa. (Albert Vrolix, *La Technique Moderne*, vol. 27, no. 9, May 1, 1935, pp. 288–289, 3 figs.)

Automatic Adjustable-Blade Turbine

AT the plant at Marmet on the Kanawha River a 7600-hp adjustable-blade turbine of a new Kaplan type will be installed. In this runner vanes are pivoted on roller bearings and connected through gears and racks to a dashpot in the runner hub. Each vane is pivoted slightly above the center of pressure which tends at all times to open or increase the pitch of the vanes. This moment is opposed by a device which creates a reactive moment that tends at all times to close or decrease the pitch of the vanes. The reactive device may be precompressed springs or any one of the several other devices.

There is, of course, a maximum-efficiency position of the vanes corresponding with the speed, head, and load under which the turbine is operating. Experiments have demonstrated that if the runner vanes are properly proportioned and pivoted, the reactive moment required to maintain best efficiency for a given installation will be practically constant within the usual variations of head and load.

The hydraulic moment increases with the wicket-gate angle, i.e., increases with load on the unit, providing the runner vanes are held in the fixed position. When the wicket gates open sufficiently the hydraulic moment overbalances the built-in reactive moment and the runner vanes are forced open. Movement of the runner vanes stops when the hydraulic moment equals the reactive moment. For each change the governor adjusts the wicket gates while the runner vanes move automatically to a new balanced position.

The vanes open wide when the turbine is started and this gives maximum starting torque. As the turbine approaches normal speed with no load on the unit, the vanes move to the closed position, after which they move to the position required by the load. (*Power Plant Engineering*, vol. 39, no. 8, August, 1935, pp. 469, 2 figs.)

INTERNAL-COMBUSTION ENGINEERING

Automobile Engine With Belt Drive Proposed for Airplane Use

THIS is the report of a 300-hr test of a well-known type of six-cylinder automobile engine connected by six belts to an airplane propeller. The belts were of the V-type running over steel pulleys. Duralumin pulleys were tried, but were found to wear too rapidly. The belt as used was found to wear on the outside layer of fabric, but at the end of the 300-hr test the belts showed fair wear, considering that they were working under very unfavorable conditions. The details of the test are given in the original paper. The main purpose of the test had a bearing on the matter of low-priced airplanes. For such a plane a low-priced engine would be required and the automobile manufacturers might be interested in lightening their engines so that they could be used for the belt drive. (*Air Commerce Bulletin*, vol. 7, no. 3, Sept. 15, 1935, pp. 43–59, illustrated, numerous tables)

Hydrogen as an Auxiliary Fuel in Compression-Ignition Engines

THE performance of a single-cylinder four-stroke-cycle compression-ignition engine operating on fuel oil alone was compared with its performance when various quantities of hydrogen were inducted with the inlet air. Engine-performance data, indicator cards, and exhaust-gas samples were obtained for each change in engine-operating condition.

Hydrogen could be burned satisfactorily at all loads up to and including cruising at compression ratios of 13.4 and 15.6 in sufficient quantities to compensate for the increase in lift due to the consumption of the fuel oil. In the cruising range the mixtures of fuel oil and hydrogen burned as efficiently as the

fuel oil alone. At small power outputs, the mixture of fuel oil and hydrogen burned less efficiently than the fuel oil alone; whereas, for power outputs greater than that required for cruising, the mixtures of fuel oil and hydrogen burned more efficiently than the fuel oil alone.

For all loads except idling there was present in the exhaust water vapor weighing more than the fuel oil burned, approximately 25 per cent more for all loads above cruising. When burning the maximum usable amount of hydrogen along with the fuel oil, the weight of water vapor was 80 per cent more at full load and 200 per cent more at small loads.

The engine always stopped firing when the fuel oil was cut off. Throughout the limits of the test conditions, it was never possible to auto-ignite the various mixtures of hydrogen and air but the injection of even a minute quantity of fuel oil would cause the mixtures to burn. The engine showed no ill effects from the use of hydrogen and no change in engine operation was apparent. (Harold C. Gerrish and Hampton H. Foster, National Advisory Committee for Aeronautics, Report No. 535, 1935, 16 pp., 17 figs.)

Distribution and Regularity of Injection From a Multicylinder Fuel-Injection Pump

A SIX-CYLINDER commercial fuel-injection pump was adjusted to give uniform fuel distribution among the cylinders at a throttle setting of 0.00038 lb per injection and a pump speed of 750 rpm. The throttle setting and pump speed were then varied through the operating range to determine the uniformity of distribution and regularity of injection.

The following are some of the conclusions that have been reached:

A multicylinder fuel-injection pump can be so constructed that even after the pump has seen considerable service the distribution between the different cylinders does not vary by more than ±3.0 per cent for all conditions of throttle above one-half throttle setting and for all speeds that are expected to be used in practice.

For loads of one-tenth throttle or less the variation in distribution may be as high as ±17 per cent of the fuel quantity being injected, although, in general, the distribution should not vary more than about ±10 per cent under this low throttle setting.

When the individual cylinders are so adjusted as to give good distribution, the time rate of discharge curves for all cylinders is quite similar.

Irregularities in the injection from each individual cylinder will occur at low throttle settings, at low speeds, or both, because of variations in the residual pressure in the injection tube.

The foregoing irregularities can be decreased by decreasing the injection-valve opening pressure, by maintaining the residual pressure in the injection tube close to the injection-valve opening pressure, or by eliminating the check valve between the injection pump and the injection tube.

The type of injection valve used, provided that the seats are in good condition, has little effect on the distribution of a multicylinder pump. (A. M. Rothrock and E. T. Marsh, National Advisory Committee for Aeronautics, Report No. 533, 1935, 12 pp., 11 figs.)

Forced-Draft Cooling for an Air-Jacketed Engine

EARLY in 1928 the possibilities of forced-draft cooling for an air-jacketed engine were put forward by R. McKinnon Wood in an unpublished paper and the present report gives the result of some wind-tunnel tests made in connection with this scheme.

Preliminary tests were made on a cylinder 6 in. in diameter, with and without fins, to find both the rate of heat dissipation to be expected from a jacketed cylinder and the power required to force the air through the jackets.

Other measurements were made on one of the finned cylinders with jackets removed or replaced by rear guide vanes and on a model fuselage of streamline form fitted with internal ducts and gauze to represent the resistance of the jacketed fins. The inlet and outlet passages were modified to produce:

(*a*) A flow induced solely by the motion of the body relative to the outside air.

(*b*) No naturally induced flow, a forced flow being supplied by a separately driven fan.

(*c*) A composite flow partly induced and partly forced.

Measurements were made of the cooling velocity through the ducts, the drag of the body, the thrust and torque of the fan. The airscrew slipstream was not represented.

The heat dissipation from an air-jacketed cylinder was found to agree reasonably well with the formula given by Osborne Reynolds, using the skin-friction coefficient applicable to pipe flow. The power required was about twice that due to skin friction for the finned cylinders and about three times for the plain cylinder.

The tests show that with a cowled system such as a Townend ring the power required for a given rate of heat dissipation can be almost halved by adding suitable rear guide vanes.

For any practical installation the power expended in cooling can be considered as the sum of (1) a necessary loss incurred across the cylinders, and (2) a parasitic loss made up of losses in the entrance and exit ducts and of the effect of the duct on the drag. For a well-designed duct this parasitic loss was found to be equal to or slightly less than the necessary loss through the jackets. Additional losses are incurred at top speed if the cooling flow increases with speed.

The data of this report are sufficient to estimate the total excess power required to provide a given rate of heat dissipation for an air-jacketed installation. This power is considerably less than with a normally cowled engine, and can be decreased still further by the incorporation of a method of regulating the cooling flow over the cylinders. (A. S. Hartshorn, Reports and Memoranda No. 1641, of the British Air Service, June, 1934, abstracted from mimeographed release)

MACHINE PARTS

Forged Gear Teeth

THE use of forging methods in the production of gear teeth has made little headway in Great Britain, although it is known that much experimental work has been carried out. Uncertainty appears to exist as to the condition of the metal after such heavy mechanical treatment. The internal crystalline structure of the metal has of course to be considered, and the blanks must be of a selected alloy steel that will lend itself to suitable hardening after the desired form has been produced. So far, most of the work has been done on nickel chrome and other nickel steels. The surfaces may then be suitably conditioned by oil-hardening or case-hardening.

The forging process does not offer any practical difficulties to the experienced forger, who seldom, however, possesses the necessary knowledge of gears themselves. Gear makers, on the other hand, are well acquainted with every detail of the gears, but do not generally understand the forging method.

There are two main problems: The forging of the teeth, and the finishing.

The final hardening need not differ from normal practice for a given steel.

The different cutting and generating hobbing operations are at the best slow, and the great accuracy and precision of the machines and tools employed is not necessarily utilized throughout. There are times when it is felt that a cruder preliminary method might be used, followed by an accurate finishing operation.

When constructing dies to form the teeth by forging the plungers must cause the dies to be fully filled out, the pressure filling all cavities in the die. Hot pressing is used with plungers which operate simultaneously, a set of plungers acting in unison on the prepared blank and pressing out the teeth in one operation. The original article tells of the many practical difficulties experienced and of the methods used. The finishing operation is comparatively briefly referred to. (*The Automobile Engineer*, vol. 25, no. 336, September, 1935, p. 322, 2 figs.)

The Mollart Universal Joint

THIS joint was originally devised to meet certain difficulties that have been encountered in the drive to the rotor head of autogiros, but it has other applications.

The ball, which may be from $^1/_2$ in. to $2^1/_8$ in. in diameter and is made of steel of 32-ton tensile strength, is formed with two grooves at right angles to one another on its surface. In each of these grooves ride the tongues of two fork members, which engage the ball, jointly, over an angle of about 250 deg. The parts of each pair of fork members are located together by tenon and groove, as shown in Fig. 2, and held in contact

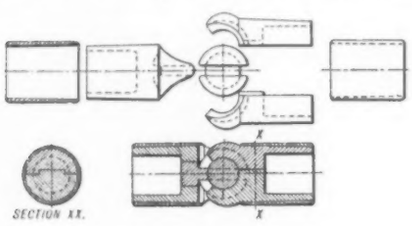


FIG. 2 MOLLART UNIVERSAL JOINT

with one another and the ball by an enclosing sleeve, which is pinned into position. The bore of the sleeve is usually slightly tapered, as also are the shanks of the fork members. For attachment to shafts the ends of the shanks are bored and can be threaded, splined, or drilled for taper pins. The grooves in the ball and the tongues on the forks are hardened and ground, and oil channels are arranged to feed the lubricant properly over the sliding surfaces. Drives can be transmitted through a maximum angle of $42^1/_2$ deg, and owing to the large arc of encirclement of the forks around the ball, the joint is capable of withstanding quite heavy stresses in tension as well as compression.

Data of tests at the National Physical Laboratory are reported. (*The Engineer*, vol. 160, no. 4157, Sept. 13, 1935, p. 265, part of an installment of an article describing the Shipping, Engineering, and Machinery Exposition at Olympia, 1 fig.)

Strength and Flexibility of Corrugated and Creased-Bend Piping

THE necessity for this investigation arose with the desire to be able to meet the increased high steam temperatures and pressures, particularly as, because of the higher reactive forces associated with the usual expansion elements, it became necessary to employ several such elements in runs of piping of moderate length. Where the steam piping changed direction large arcs were necessary and it was in order to provide increased flexibility and permit forming of bends on a smaller proportion of bends to pipe diameter that the so-called corrugated piping and creased-bend piping were developed.

The investigation had the following objects: First, to determine the relationship between the load and deflection for various shapes of corrugated and creased-bend pipes in order to establish their flexibility relatively to smooth-walled pipe; second, to determine the endurance properties of the corrugated and creased-bend pipes under cyclic stressing; third, to develop methods for measuring the strains induced in these pipes under load and interpreting the significance of these strains; and finally, to derive values for safe working stresses for these pipes for the purpose of piping-system design.

The paper is far too extensive for an abstract here. It covers the early experimental work on expansion bends, von Kármán's development of the theory of flexibility of pipe bends, and the important extension of the work carried out at the Massachusetts Institute of Technology by Prof. Hovgaard.

From this the author proceeds to a consideration of the strength of pipe bends and design of piping under considerations of variable stress including the consideration of limitation of the theory of elasticity in analyzing stresses in this kind of piping.

The general scheme of investigation is as follows: The presence of corrugations or creases in a pipe, while increasing the flexibility, also acts to increase the stress. If fatigue tests are made on these pipes so as to determine an endurance limit for each given type, it will develop that the stress at this endurance limit when computed from the ordinary Rankine formulas of mechanics is far different from the stress corresponding to the known endurance limit of the steel. For the purpose of determining the stress at which the pipes were operated in fatigue tests the bending formula was used

$$S = Mc/I$$

In this formula, M is the value of the applied bending moment, I/c is the value of the section modulus of the basic pipe. In order to determine this value, the moment of inertia I of the cross section was computed from dimensions of the pipe before being corrugated or creased. The value of c was likewise taken as the radius of the outer surface of the basic smooth-walled pipe. This equation then yields values for stress S which are nominal values. The term "nominal stress" has been applied to this quantity. The ratio of the endurance limit for the steel to the endurance limit of the pipe, when the latter is expressed in terms of nominal stress, will then be a direct indication of the stress multiplication effect due to the corrugated and creased-bend shapes. The writer has called this factor the "stress-intensification factor" and has given it the designation N.

In addition to the determination of the stress-intensification factor, a method was developed for determining the stress distribution in pipes from internal pressure and from applied bending moments. This method employs the use of strain gages applied to the outside of the pipe wall and involves the calculation of the critical stresses at the inner pipe-wall surface derived from these external strain measurements.

The actual experimental work carried out, including that of the nature of fatigue failures and analysis of strains and stresses, is given in the original article. (Lt. Robt. L. Dennison, in *Journal of the American Society of Naval Engineers*, vol. 47, no. 3, August, 1935, text pp. 343–408, and illustrations pp. 409–432)

MACHINE-SHOP PRACTICE

Welding Bronze to Steel

WHEN depositing welding bronze onto steel two important points should be remembered: First, the two

metals must be brazed and not fused; second, the deposited bronze must be cooled quickly enough to prevent porosity as a result of liquation, i.e., separation of component metals resulting from differences in their melting temperatures.

If the bronze and steel are fused some of the iron will be absorbed by the bronze and a porous deposit will obtain. When the materials are brazed none of the iron is absorbed. To braze bronze onto steel it is important that the steel is not welded but heated to the brazing temperature, which is a dull-red heat. The arc is directed onto the deposited bronze and not the steel. The steel should be heated

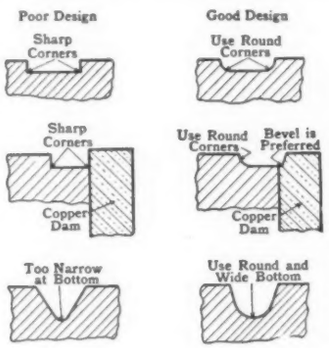


FIG. 3 POOR AND GOOD DESIGNS FOR BRONZE OVERLAYS ON STEEL

by conduction from the molten bronze and not by direct contact with the arc.

The effect of liquation is discussed in the original article and the welding procedure set forth in detail.

The matter of joint design is a factor materially affecting the success or failure of the operation. In many welded-bronze overlays on a flat surface the greatest difficulty is encountered when it is necessary to make the bead of uniform width with a deposit built up in two or more layers. In such cases dams have to be used and heavy copper makes a suitable dam.

When the bronze is to be deposited into a groove in a plate it is essential that sharp corners and narrow grooves be not present. Exterior corners are easily fused into the deposit while re-entrant corners and narrow grooves foster incomplete union between the bronze and the steel.

When using copper dams there are two points to be remembered. First, the chilling effect of the dam causes the deposited bronze to freeze with surface pits on the side adjacent to the dam. This is not a serious condition, however. If at least $^1/_8$ in. is to be machined from the surface, all the surface pits will be removed. Second, if the groove is too deep or narrow there may be trouble from arc blow. When using a copper dam on one side of the arc there is a tendency for the arc to blow toward the copper. This results in the arc being frequently blown out. (Charles H. Jennings, Research Engr, Westinghouse Elec. & Mfg. Co., *The Electric Journal*, vol. 32, no. 8, August, 1935, pp. 317–318, 3 figs.)

MARINE ENGINEERING

Garratt Auxiliary Propeller Drive

THE idea of auxiliary propeller drive is not new, but in the older systems the position of the auxiliary propeller in relation to the main propeller was such as to make it impracticable to obtain efficient utilization of the power that could be transmitted to the shaft.

This is said to have been overcome in the Garratt system where the auxiliary propeller is situated forward of the main single screw and a little to one side, so that the flow of water into and from the auxiliary screw will not interfere with the efficient functioning of the main propeller. It is said that tests have shown that with this location of the auxiliary screw the influence on the steering of the ship is negligible. The auxiliary propeller is chiefly intended to be used in connection with the Bauer-Wach system of drive, and it is even proposed to drive the auxiliary propeller by an electric motor, the exhaust turbine then driving an electric generator. (*The Marine Engineer*, vol. 58, no. 695, August, 1935, pp. 211–212, illustrated)

MOTOR-CAR ENGINEERING

Russian Diesels

THE article deals exclusively with Diesel engines for use in motor cars and motor tractors. Information is given in the form of a specification table on six of these types. The type ATB was built without the use of foreign materials or parts. It is a two-stroke-cycle engine in which 25 per cent of the piston stroke is occupied by scavenging ports. A separate scavenging pump is provided for each cylinder. In the fuel pump the injection takes place during the whole of the delivery stroke of the pump plunger. But the initial moment of injection does not depend on the quantity of fuel injected, the control of this quantity being effected by the axial displacement of a variable profile cam.

Among the merits of the engine its comparative indifference to the various grades of fuel may be especially noted. The engine would run with practically the same results on soldar oil having a specific gravity of 0.890 at 15 C or on motor oil with a specific gravity of 0.914 at 15 C and water content of 1 per cent. The engine can easily be started with the aid of fuses at a temperature of surrounding air of +5 C and an air pressure in the container not less than 12 atm. The starting-air container can be quite satisfactorily charged by the engine to a pressure of approximately 27 atm. (N. R. Brilling, *The Automobile Engineer*, vol. 25, no. 336, September, 1935, pp. 333–336, 4 figs.)

POWER-PLANT ENGINEERING

Steam Storage in a Power Plant

WHILE there is nothing new in the following data on how storage improves the performance of steam plants, the article is abstracted here because it brings these data together.

(1) Raising the average pressure of a turbine. The initial pressure of the turbine was found on an average to be 0.5 atm, higher after the installation of the steam storage. As the average initial pressure available was 13.5 atm, this shows that the heat drop has been raised by about 0.5 per cent and a saving in the consumption of coal of 0.4 per cent has been obtained.

(2) Increase in the average temperature of superheat of the steam. It would appear that the average temperature of superheat of 330 C at the entrance to the turbine can be raised by 10 C. This increases the heat drop by 1 per cent and the saving in coal by 0.8 per cent.

(3) Increase in the average CO_2 content and maintenance of lower temperature of the exhaust gases. These may be expected where the load on the furnace is maintained more uniform. A reduction of the exhaust-gas losses from 13.4 to about 11.4 per cent seems to be possible and that would mean a saving in coal of 2 per cent.

(4) Elimination of safety-valve losses which seem to be unavoidable where the daily load curve shows strong peaks. With the installation of steam storage the latter takes care of the excessive steam. The saving estimated is about 0.3 per cent.

(5) Reduction in the amount of reserve that the boilers must maintain. It is said that in 1930 the maintenance of a reserve on the boilers alone caused the coal consumption of 1.6 per cent. If a constant-pressure storage is available the plant may be handled so that a given

amount of steam as high as 28.5 lb per hr may be taken over by the plant when the boiler is cut out.

(6) Because of the far more uniform loading of the heating surfaces of the boiler as a result of the installation of a steam-storage system the rest periods become shorter. In 1932 in the plant under consideration this amounted to 19.3 per cent. The installation of a storage system is said to permit a reduction of 2 per cent resulting in a corresponding reduction in the coal consumption of 2 per cent.

All of these sources of saving give a total saving in coal consumption of 6.8 per cent, which for a total consumption of 104,000 tons gives about 7000 tons per year. On the other hand, one must consider the following losses due to the presence of a steam-storage plant:

(1) The cooling of the surface of the storage plant with an area of 235 sq m produces a temperature difference of 200 C and results in a loss of 0.5 kcal per sq m per hr per deg C difference, and gives an annual loss of 204×10^6 kcal equivalent to 151 tons of coal.

(2) The power consumption of the circulating pumps and two-stage feed pumps costs 620 tons of coal. The installation of a steam storage plant is therefore likely to give a saving of only 6309 tons per year. (Franz Mühlhausen in *Archiv für Wärmewirtschaft und Dampfkesselwesen*, vol. 16, no. 7, July, 1935, pp. 171–175, 6 figs.)

Electric Generation of Steam

THE principal loss of heat in the operation of an electric steam generator is that resulting from the bleed from the generator to maintain the proper conductivity. For a concentration of dissolved salts of not more than 60 ppm or a resistivity of not less than 6000 ohms per inch cube at 20 C, the generator will operate without excessive bleed. The formation of scale is not harmful except that, if allowed to accumulate in the bottom of the tank, it may clog the bleed outlet.

In some localities where organic matter is present in the feedwater, the scale may adhere to the electrodes and interfere with the flow of the electric current. In some such instances, the electrodes are cleaned as often as once a month. The electric steam generator is subject to corrosion and pitting the same as fuel-fired boilers. It has the disadvantage that dissolved salts may not be used so freely in treating the water, and the advantage that the pressure shell may be protected by scale or other suitable coating. (First of a series of articles by C. R. Reid, Asst. Gen. Supt. of the Shawinigan Water and Power Co., in *Electrical News and Engineering*, vol. 44, no. 16, Aug. 15, 1935, pp. 27–30, 5 figs.)

Protection of Smoke Passages of Vertical Boilers

USERS of vertical steam boilers have found corrosion to be particularly rapid in the central passage leading from the steam chamber, especially in the neighborhood of the average water level. This corrosion results from the fact that the iron sheets not being cooled by the water are affected by the action of gases which are still very hot. An attempt has been made to combat this condition by putting a sheet-iron or cast-iron sleeve in the interior of the stack in order to protect it against direct contact with the gases, but the results obtained thereby have not been very encouraging. It is well known that replacement of a corroded stack is an expensive job and yet if it is not done in time, grave consequences may result.

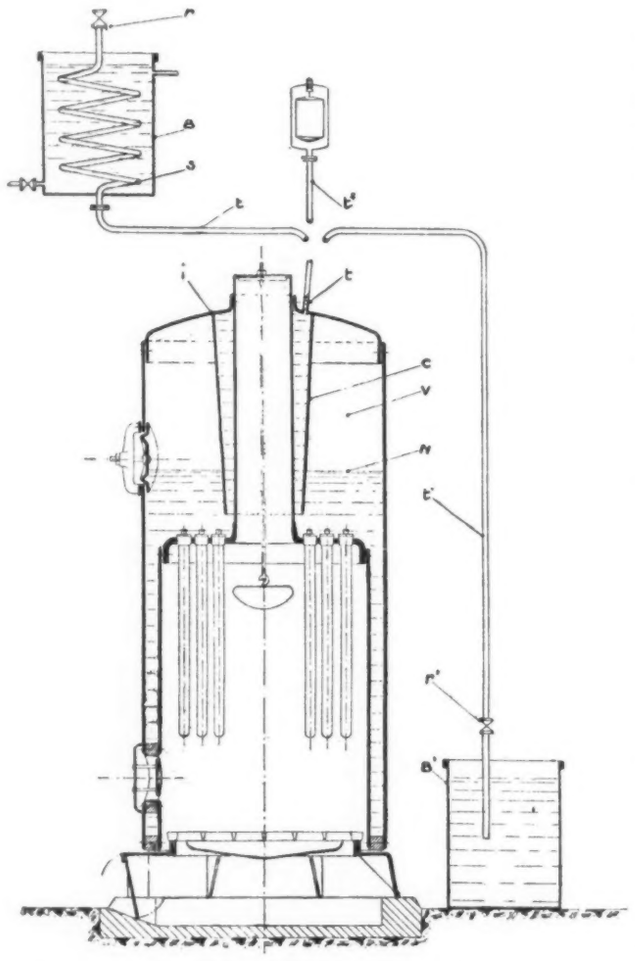


FIG. 4 DIAGRAMMATIC VIEW OF A DEVICE FOR PROTECTING CERTAIN PARTS OF THE STACK AGAINST CORROSION

The device described in what follows is said to be inexpensive and yet it keeps the stack at all times in contact with water, which prevents overheating of the sheets. The device consists of a cylindrical sheet-iron jacket *C*, Fig. 4, welded or riveted to the dome at *i* and descending below the average water level. In the upper part of the annular chamber thus created a pipe *t* is provided which may be connected to coil *S* immersed in a water tank *B*, or else in place of *t* may be provided tube *t'* having a cock *r'*. The latter may be replaced by an automatic float valve.

When the boiler is cold the water level is, let us say, at *N* in the steam chamber *V*, and within the annular space constituted by the jacket *C*. As soon as the pressure in the boiler begins to rise the air is permitted to escape through cocks *r* or *r'*.

The result is that under the influence of the pressure obtaining in the steam jacket *V*, the water rises in the annular space filling it completely and finally escaping through the cocks *r* or *r'*. At this moment the cocks are closed and the column of water is maintained by the pressure existing in the boiler. The steam which forms inside of the jacket and in contact therewith condenses in the coil as it forms. If a simple cock *r* is used, all that is necessary is to provide a small continuous flow to the feed tank in order to insure that the pressure in the annular space is always lower than in the boiler. This flow may be maintained automatically by means of a float-type escapement valve, and means may be provided to return the steam that escapes back to the tank. Whichever of these three methods is selected, the apparatus is said to give efficient pro-

tection of stack. (A. in *La Technique Moderne*, vol. 27, no. 9, May 1, 1935, p. 299.)

RAILROAD ENGINEERING

German Streamlined Locomotives

THE locomotives described in this article are of the 4–6–4 type, apparently of the generally standard design, but are equipped with streamlined shrouding. With a boiler pressure of 284 lb and three single-expansion cylinders $7^{11}/_{16}$ in. × 26 in., these locomotives are designed for a sustained speed of 93 mph, and a maximum speed of 109 mph. This is with a load of four to five coaches carrying from 200 to 300 passengers.

The rated tractive force on an 85 per cent basis is 32,600 lb and the anticipated horsepower is 2764 ihp. The shrouding has been carried down almost to the rail and covers up the running gear and motion work, sliding covers being provided for the necessary inspection and lubrication. There was some anxiety as to possible heating of bearings resulting from their enclosure, but tests have shown that no difficulties in this direction are to be expected. The locomotive was equipped with the parabolic cap on the smokebox and the cab was given a tapered form.

The tests showed a saving of from 500 to 700 hp at a speed of 87 mph due to streamlining. Part of the saving, however, may have resulted from a decrease of heat losses from the cylinder and steam-chest walls. The details of construction are given in the original article.

The next high-speed streamlined locomotive, which is now being built, will be arranged to burn pulverized coal. In this locomotive the cab will be located at the front end ahead of the smokebox. (*The Railway Age*, vol. 79, no. 4, July 27, 1935, pp. 107–109, 1 fig.)

REFRIGERATION

Efficiency of Refrigerators

SIGNIFICANT tests to compare the performance of domestic electric refrigerators can be made with such simple equipment as that with which most electrical and mechanical laboratories are familiar. Nevertheless, if strictly comparative results are to be secured, it is necessary that some standard tests and standard test procedures be followed and that steps be taken to maintain the desired conditions throughout the tests. Moreover, if test results are to be helpful from the standpoint of the manufacturer as well as of the purchaser and user of the refrigerator, measurements must be such as to show the effectiveness of the assembly in units that are significant under operating conditions.

Thus far electrical manufacturers have not agreed upon tests or procedures of industry-wide acceptability. Light and power companies, however, as purchasers and distributors of domestic electric refrigerators, are interested in the degree of service satisfaction to be anticipated from such equipment and have cooperated with the Electrical Testing Laboratories, operated largely in their interest, in the investigation of the performance of modern home refrigeration units. Under the direction of the Appliance Committee of the Association of Edison Illuminating Companies many tests have been conducted. As a result of this work there has been formulated a set of specifications under which comparative performance can be measured and judged.

The tests may be grouped as operative, those dealing with safety requirements, and structural requirements. They also limit the maximum starting current and provide that during a 19-day test the machine shall not develop leaks or other faults which require the use of tools by a service mechanic. A number of tests were carried out both on the conventional small domestic refrigerators and on similar but less expensive refrigerators. It was found that some makes show double the energy consumption of other makes under some temperature conditions, and several makes are consistently better than others at all temperatures. Some of the refrigerators have cooling systems which operate continuously when the refrigerator is in an ambient temperature of 110 F and the same ones operate about half or more than half the time at a room temperature of 90 F. Power demands vary from 150 to nearly 300 watts as between different makes. Tests on the lower-priced units show results quite similar to those obtained with the more expensive types. (*Electrical Manufacturing*, vol. 16, no. 2, August, 1935, pp. 13–16, illustrated)

STEAM ENGINEERING

An Industrial High-Pressure Boiler With Welded Drums

THE boiler unit is of an unusual design, as it consists of a single bank of nearly vertical tubes connected to an upper and lower drum. It has a heating surface of 2750 sq ft, corresponding to an actual evaporative rate of 7.3 lb per sq ft per hr at maximum rating.

Feedwater enters the main steam and water drum near the ends, thus supplying directly, the down-take tubes which are located at the ends of the drum. These tubes are not exposed to the gases, but are protected by being built into each of the side walls, and therefore provide a positive feed to the bottom drum.

All the boiler tubes forming the actual heating surface are thus free to act as steam risers. The first line of tubes consists of half a row only, to form a slag screen, and both this and the next row of tubes are exposed to the radiant heat of the furnace and discharge above the water level into a baffle trough having openings at the ends, thus allowing the large volume of steam generated in these tubes time to separate from the entrained water in the mixture. Further separation of the moisture, insuring the production of dry steam, is obtained by passing the steam into the receiver drum, which is located directly above the steam and water drum.

The remainder of the heat-extraction plant consists of an M.L.S. superheater located at the back of the boiler tubes after the first pass, a B. and W. economizer of the cast-iron gilled-tube type and a Usco air heater.

The fuel consists of a mixture of coal (Scotch washed singles) and works refuse, comprising vegetable wastes from the distilleries, straw, paper, and wood chips. Until recently it was considered necessary to use step-grate stokers where the amount of rubbish exceeded 20 per cent in volume of the coal fired. There was therefore some considerable hesitation in adopting a traveling grate, particularly as the factory where this plant is installed is located in a densely built-up area, and a total absence of smoke during all periods of operation is essential.

The principal features of interest in the construction of this boiler lie in the fact that it is the first plant to operate in Great Britain with drums of entirely welded construction. The manufacture was carried out according to the requirements laid down by the Boiler Code Committee of the A.S.M.E. (*The Steam Engineer*, vol. 4, no. 10, July, 1935, pp. 430–432)

New Method of Graphic Presentation of Steam Consumption of Bleeder Turbines

IT IS CLAIMED that by the use of this method more precise information can be obtained as to the operation of the turbine, particularly at part load. The usual way of presenting the steam consumption of bleeder turbines at part load is shown in Fig. 5, which, as will be

shown later, is not satisfactory. The high-pressure section must often be proportioned so generously that it alone could carry the entire load within the range of back-pressure operation. At half load and light bleeding, only a fractional share of the throughput capacity of the high-pressure section is utilized. This may affect quite unfavorably the economic part of the operation, particularly where there is no precise knowledge as to the dependence of the factors on each other. The method of presentation developed in this article is supposed to supply this information. The best way to explain this new method of presentation is by means of an example taking as a basis the data of Fig. 5. The steam consumption will appear to be as in Table 1.

These tests are based on a heat drop in the high-pressure section of 90 kcal per kg and in the low-pressure of 132 kcal, with an overall efficiency of 62.5 per cent in the high-pressure and 82 per cent in the low-pressure side. The high-pressure section consists of a two-row impulse wheel controlled by three nozzle valves. The throughput capacity amounts to 4250, 7600, and 11,000 kg of steam per hr. This steam is being utilized at constant overall efficiency because the nozzles are fully loaded all the time.

The author investigates the effect of throttling on the first group of nozzles having 4250 kg throughput capacity. The pressure is throttled from 18 atm abs to 14, 10, 6, and 4 atm abs, the latter being the bleeder pressure.

The overall output obtained depends then on the weight of the steam, the remaining head, and the efficiency. These data are given in Table 2. Because of the "cone of steam weights" (Stodola, 6th edition, p. 262) the throughput of the steam varies in accordance with the hyperbola, the vertex of which is given by the back pressure and one of its points by the total output (Fig. 6). Any decrease of the heat drop can be immediately read from the entropy table. A reduction in efficiency can be estimated from Fig. 7. As will be shown, however, this is a matter of comparatively negligible importance.

The work performed by the two turbine parts is separately given in Fig. 8 where the data referring to the high-pressure section are above the zero line and those to the low-pressure are below, both in terms of overall output. The behavior of the nozzle group 1 based on Table 2 is shown in the extrapolated curve *0-II*. The broken line shows the process as it would have been if the efficiency had not be cut down by throttling. It will be easily seen that the effect of this factor is small and the general assumption suffices.

The points for the second and third groups of nozzles, wide open, lie (assuming the same efficiency) on the straight extrapolated connecting line *0-II*. These points are *IV* and *VI*, with overall outputs of 497 and 720 kw. The effect of throttling can hardly be very

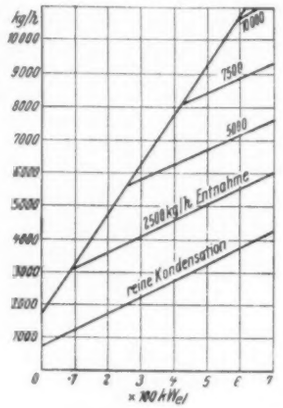


FIG. 5 CONVENTIONAL DIAGRAM OF STEAM CONSUMPTION OF A SINGLE-CYLINDER BLEEDER TURBINE

(n = 5500/1000; 700 electrical kw; 20 atm abs and 380 C; 4 atm abs; water 62 C; maximum bleeding = 10,000 kg per hr; kg/h = kilograms per hr; *Entnahme* = bleeding; *reine Kondensation* = pure condensing.)

different from that in the first stage. It is therefore represented by similar estimated curves describing the same process. For purposes of easier transfer, which will later be shown to be necessary, a straight-line polygon *0-I-II-III-IV-V-VI* is plotted around the curves. As these lines cover the curves practically completely, this approximation might be used more extensively.

What happens in the low-pressure section is determined in a somewhat different way. The flow of heat amounting to 132 kcal per kg remains the same at all loads. The weight of the throughput depends not on the throttling but on other conditions, such as load and bleeding. The outputs obtained for different weights of steam depend exclusively on the overall efficiency. If it is

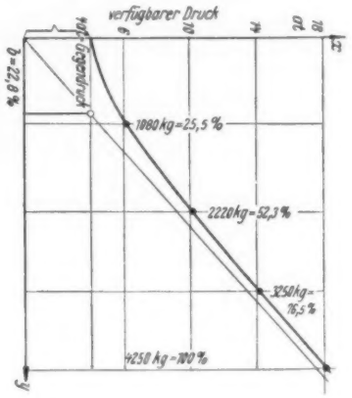


FIG. 6 THE STODOLA HYPERBOLA

(*Gegendruck* = back pressure; ordinates = available pressure in atmospheres.)

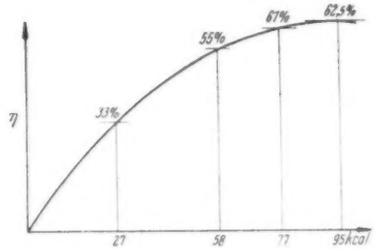


FIG. 7 REDUCTION OF HIGH-PRESSURE EFFICIENCY WITH REDUCTION OF HEAD

estimated that the variation of throughput from zero to maximum occurs somewhat parabolically, increasing from 0 to 82 per cent and culminating at that value, there correspond to weights of steam of 1000, 2000, and 4250 kg per hr, efficiencies of 39, 61, and 82 per cent, and overall outputs of 58.5, 188, and 535 kw. The corresponding line is plotted below and designated by *0-VIII;* it may be replaced by the two straight lines, *0-VII-VIII*. Point *VIII* corresponds to full output with nozzle group *I* of the high-

TABLE 1

Electrical output, kw	700	350
0 kg per hr bleeding, kg per hr	4250	2650
5000 kg per hr bleeding, kg per hr	7600	6100
10,000 kg per hr bleeding, kg per hr	11,000	..

TABLE 2 OVERALL OUTPUT OF HIGH-PRESSURE SECTION AND THE FIRST NOZZLE AT VARIOUS DEGREES OF THROTTLING

Available pressure, atm abs	18	14	10	6	4
Weight of steam, kg per hr	4250	3250	2220	1080	...
Heat drop, kcal per kg	90	77	58	27	...
Overall efficiency, per cent	62.5	61	55	33	...
Overall output, kw	277	178	82.5	11.2	...
Overall output at η = 62.5 per cent, constant	277	182	86	21.3	...

pressure section wide open and no bleeding taking place.

From this the author proceeds to compare what happens in the case of a reciprocating engine. This is omitted because of lack of space.

A useful way of presenting turbine operation giving output at the couplings

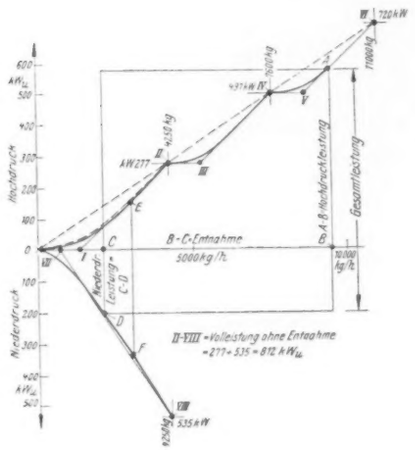


FIG. 8 OVERALL OUTPUT VS. STEAM CONSUMPTION

(*Hochdruck* = high pressure; *Niederdruck* = low pressure; *Vollesitung ohne Entnahme* = full output without bleeding; *Niederdr. Leistung* = low-pressure output; *Entnahme* = bleeding; *Hochdruckleistung* = high-pressure output; *Gesamtleistung* = total output.)

or at the generator bus bars can also be obtained by using a variable scale for the output. To do this the high-pressure line is at all times so shifted that the overall output corresponds to the desired output at the bus bars. Overall output is shown by the displaced curve jointly with the bus bar output. The overall output itself can be obtained from Table 3. The generator losses in accordance with proper curves of efficiency are determined for cos $\varphi = 0.8$. The values at no load are extrapolated and the mechanical losses are assumed to be not higher than 6.5 per cent. The operating losses are assumed to be constant and amount to 15 kw and the wheel-friction and windage losses are likewise assumed to be constant and to be 15 kw. The diagrams in Fig. 9 have been plotted on the basis of these data. The maximum load is here 684.5 kw, which means somewhat less than in Fig. 5. This is due to the fact that in Fig. 5 it has been assumed that cos $\varphi = 1$ and a somewhat higher efficiency is obtained thereby. The example plotted, 400 kw, 3500 kg of bleeder steam, gives a total steam consumption of 5575 kg per hr and 2050 kg per hr of condenser steam.

Fig. 9 should really speak for itself. It may be of interest, however, to add a few words as to the meaning of the various boundary lines, as well as to the fact that more shifted high-pressure lines have been plotted than there are corresponding points capable of evaluation. Only points below the base line will be considered here.

TABLE 3 OVERALL OUTPUT AT VARIOUS LOADS

Electrical load, kw	0	100	200	300	400	500	600	700
General losses, kw	21	24.6	28.4	32.8	37.4	42.4	47.3	52.5
Mechanical losses, kw	31	33	35	37	39	41	43	45
Gear transmission losses, kw	15	15	15	15	15	15	15	15
Ventilating and wheel-friction losses, kw	15	15	15	15	15	15	15	15
Total overall registered kilowatts and consequently measure of downward displacement of high-pressure curve	82	187.6	293.4	399.8	506.4	613.4	720.3	827.5[1]

[1] Without steam extraction maximum capacity according to Fig. 8 is only 812 kw total. Maximum terminal capacity is therefore only 684.5 kw.

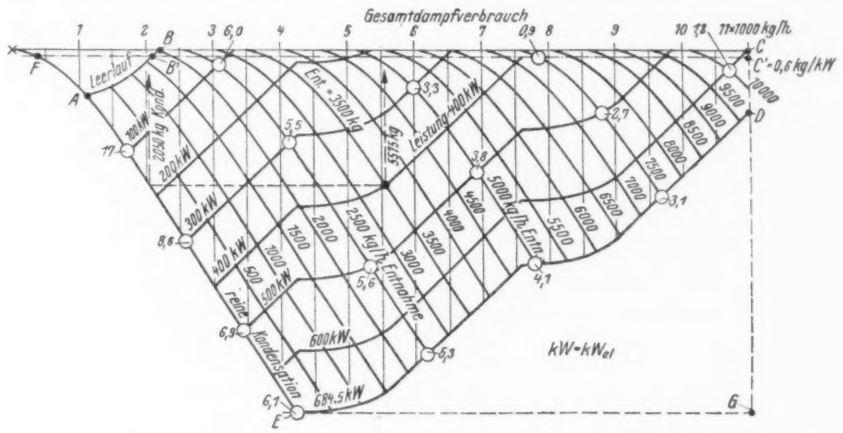


FIG. 9 DIAGRAM OF TOTAL CONSUMPTION—OUTPUT—BLEEDING—AND CONDENSING

(The numbers in the circles show condensing steam in kg per kwhr)

(*Gesamtdampfverbrauch* = total steam consumption; *Leerlauf* = operation at no load; *reine Kondensation* = pure condensing operation; *Entnahme* = bleeding; *Leistung* = output.)

AB is the no-load line where bleeding can be effected only at point *B*. For greater bleeding it is necessary to have either a load or an addition of live steam. *BC* shows the most favorable relations between load and bleeding. The low-pressure side carries no load and receives no steam, while the high-pressure side runs as a back-pressure engine. A device is provided to supply to the low-pressure side the minimum amount of steam without which it will not run. This may be indicated by *F*. The line *BC* shifts to *B'C'*, in which case only the part below in the diagram is subject to evaluation. *CD* corresponds to an increase of load above *C*, which is possible only with a reduced or originally slight bleeding.

DE is the highest load which can be put out under any conditions from pure condensing operation to bleeding from *D*. Additions of live steam are necessary in this case because of the extra consumption of heat; if the load possibilities of the generator are higher, the points of the area *DEG* can be used in addition to bleeding. This is, however, a dangerous operation, because in case of an unforeseen reduction in bleeding the load could not be carried.

AE is the line of pure condensing operation at all loads from zero to *E*. It is assumed here that artificial means are employed to maintain the bleeder pressure.

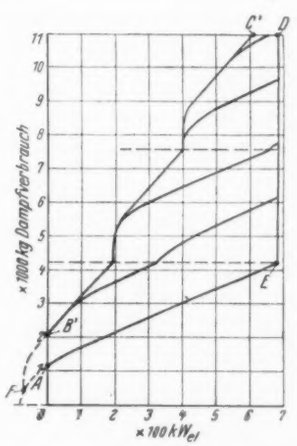


FIG. 10 FIG. 9 REDRAWN TO CONFORM TO FIG. 5

(*Dampfverbrauch* = steam consumption.)

If the governor is cut out, most favorable steam consumption sets in. For this the line *AE'* has been plotted.

Had Fig. 5 been correct, it should have shown the same relations as Fig. 9. This has not proved to be the case, as shown in Fig. 10, which is Fig. 9 redrawn to conform to Fig. 5. At first glance one sees the great deviations and lack of correctness of the former, particularly at partial load. (Rudolf Schlenk in *Archiv für Wärmewirtschaft und Dampfkesselwesen*, vol. 16, no. 8, August, 1935, pp. 217–219, 7 figs.)

LETTERS AND COMMENT

Lubrication Program

TO THE EDITOR:

The authors of the recent paper entitled "A Lubrication Program,"[1] referred to greases as being soaps which act as a vehicle for the mineral oil. When the oil is added to a soda, calcium, aluminum, or lead soap, certain chemical interactions take place which modify the nature of the oil. For example, the fats from the soap intermix with the oil, increasing its oiliness, adherciveness, and film strength. The popular conception of a grease is that of a heavy jellylike mass. In reality any mineral oil whose viscosity has been increased by the addition of a soap, however slight, becomes technically a grease. No sharp distinction between oils and greases can therefore be made, the principal difference consisting in gradually increased viscosity or consistency.

MAURICE RESWICK.[2]

TO THE EDITOR:

This paper[1] shows the benefits to be derived when the owner exercises his authority over the lubrication of his own machinery. The machine owner has always had to accept all liability for the lack of lubrication, and the costs are his to pay when lubrication is scanty or faulty. If the design or structure of the machine is such that its full potentialities can never be realized, no one but the owner suffers. And, as has been pointed out in this paper, apparently the only method that is at all practical for stopping such losses is for each owner himself to accept full responsibility for their elimination through an organized study in his own plant of each machine's particular requirements.

The paper mentions one factor that cannot be tolerated in many industries—that of oil throwing or dripping. An engineer making a study of this will be forced to take up bearing design as well as method of oil application. If a new sealed-bearing design is developed, then comes the question of cost of the machines to which it is applied. Such machines can be shown to earn their cost many times over, because oils can be used that will save power. More money can be saved than by using oils heavy enough not to drip but resulting in a greater loss of power. The same methods of approach to the problem of machine adjustment, wear, or noise from vibration can be made a part of the program. Each objective attained will bring about substantial savings in operating cost or increases in production through reducing certain losses. The lubrication-engineer's work consists almost entirely in eliminating losses.

Invariably, and from the motive of self-advancement, the man in charge of such work will be found to be organizing everyone having to do with machine and tool operation, as it is soon apparent that complete results can never be secured without the cooperation of the entire operating personnel. Then there comes the necessity for keeping this personnel interested, so as to continue the program.

Automatically, a system is set up, as has been shown in this paper, for plant personnel education. No one ever heard of an "oiler," as regularly employed, setting up an educational system for the purpose of securing the cooperation of everyone else for the accomplishment of some objective of plant economy. Such things are done only by some man having a deep-seated interest in his general personal work, and this requires a broader field of endeavor than operating a squirt can.

The paper also contains suggestions for the machine designer. Isn't the next general move in the use of the sleeve bearing to make this dirt-proof and oil drip-proof? Many factors will have to be finally reviewed by the lubrication engineer in his study of machinery, including bearings, their long-time efficiency, adjustment for close clearances, starting torques, running efficiencies, noise from vibration, cost of power, cost of attention, and cost of lubrication and general maintenance. But when everything is included in design and in the construction of the machine and all that that includes, how is the user ever to secure these potentialities without including the machine in a well-organized lubrication program? Such a program has been well indicated in the paper under consideration.

WILLIAM F. PARISH.[3]

TO THE EDITOR:

Mr. Reswick has called attention to a point, i.e., the difference between an oil and a grease, which may not have been made entirely clear in the paper.[1] As he states, any mineral oil to which any quantity of soap, however slight, has been added, "becomes technically a grease." The point which the paper endeavored to emphasize is that grease is inherently unstable and tends to separate, and that grease as popularly conceived as "a jelly-like mass" has a relatively high percentage of soap. Separation of the oil and soap is likely to give trouble, especially if unrecognized or unanticipated, and if, therefore, no provision has been made to guard against it. Oil is to be preferred for use as against grease, and if grease must be used, lubricating devices, servicing, and inspection methods, as well as maintenance provisions, must be suitable for such use.

As to the need of greater lubrication consciousness and education, for which Mr. Parish makes such an earnest plea, we are already on the way. Some industries are way in front; others are far behind. However, with the increased recourse to automatic machinery, high relative capital investment for equipment, and high consequent machine-hour cost as against labor cost, interruption to service, high repair expense, or inefficient "time use of plant," due to faulty lubricants, devices, or services, will not be long tolerated.

VIRGIL M. PALMER.[4]

[1] "A Lubrication Program," by Virgil M. Palmer and Horace F. Smith, MECHANICAL ENGINEERING, September, 1935, pp. 565–570.

[2] Standard Oil Co. of New Jersey, New York, N. Y. Mem. A.S.M.E.

[3] Chairman, Lubrication Engineering Committee, A.S.M.E. Machine Shop Practice Division.

[4] Engineer of Industrial Economy, Eastman Kodak Company, Rochester, N. Y.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Identification of Firearms

IDENTIFICATION OF FIREARMS From Ammunition Fired Therein With an Analysis of Legal Authorities. By Jack D. Gunther and Charles O. Gunther. John Wiley & Sons, Inc., New York. 1935. Cloth, $5^3/_4 \times 9$ in., 342 pp., 148 figs. $4.

REVIEWED BY HARRY F. BUTTS[1]

IN view of the high percentage of crimes of violence by shooting, this work is very timely for those engaged in the investigation of such crimes, as well as for those connected with the administration of justice. As E. M. Morgan, Bussey Professor of Law, Harvard Law School, states in the foreword in summarizing the book as a whole, "it is the purpose of this book to make an honest exposition of the science of firearms identification in its relation to the judicial process. It is the result of long-continued and accurately controlled experiments with numerous specimens of various types and manufacture both of weapons and of ammunition. It neither exaggerates nor underrates the value of the function which the honest expert can perform. It does not disguise the evils that dishonest or ill-equipped experts may do. It should be an effective aid to court and counsel."

In the first chapter of 102 pages there is found for the first time a sound logical and rigorous development of the principles of the science of the identification of firearms from ammunition fired therein. This development perforce demonstrates that there is a veritable gap between proving that a given bullet was fired from a firearm of a certain manufacture and determining that a given bullet was fired from a particular firearm and no other. The authors stress the point that the art of identification demands reasoning based on similarities and differences, and this is convincingly illustrated by excellent photomicrographs. This chapter is followed by an appropriate quotation from Bacon: "If a man will begin with certainties, he shall end in doubts; but if he will be content to begin in doubts, he may end in certainties."

The second chapter is devoted to the famous Sacco-Vanzetti case. It contains an analysis of the expert testimony on firearms identification and the treatment of such evidence by the court and the attorneys for the Commonwealth and the defense. This complete discussion fully demonstrates the vital importance that may be played by testimony on firearms identification, and the necessity for having court and counsel aware of the limitations and extensions of the science.

The third chapter should be read by every lawyer and judge who is connected with criminal proceedings and particularly those members of police departments who are concerned with the apprehension of criminals and the collecting, safeguarding, marking for identification, and establishing the chain of possession of such evidence so that it may properly be admissible in courts. By a chronological analysis of the cases the authors trace the application of the science of firearms identification in court. The cases are discussed individually and many excerpts from the expert testimony are given and critically analyzed, both from the legalistic and the scientific point of view.

It is the only book of its kind available in so far as it points out the strength and shortcomings of particular cases. This chapter succinctly points out mistakes that have been made in the past and which should serve as danger signals in the future. This chapter also includes suggestions for the presentation of this expert testimony as well as suggestions and an invaluable set of questions for the cross-examination of witnesses presented as experts in the identification of firearms.

The authors of this book, one a lawyer, the other a professor of mathematics and a Lieutenant-Colonel in the Ordnance Department in the Army of the United States, form a happy combination for their task and display a thorough knowledge of the subject matter with which they deal.

As indicated by the purpose of this book, it confines itself to fundamental principles and these are not clouded by the inclusion of tables of rifling specifications, and other accumulations of data which, for their limited use, can be found elsewhere.

REVIEWED BY GEORGE H. DESSION[2]

This is a concise little handbook, very well adapted to the need of counsel and court when confronted, time-pressed and unschooled in the premises, with alleged expert evidence on firearms identification to be presented, refuted, and understood. It is also a most enlightening and not undisturbing critique of "ballistics" opinions and judicial rulings on this character of evidence to date—opinions and rulings on which the question of guilt or innocence for so many a defendant on trial for his life in the criminal courts has turned. The product is one of collaboration between representatives of the two distinct professions involved, the authors being respectively a member of the Bar of the State of New York and a mechanical engineer holding a commission as Lieutenant-Colonel of Ordnance in the United States Army, a professor of mathematics at the Stevens Institute of Technology, and practicing as an expert in this field.

The scientific foundation of this study is found in chapter 1, consisting in a 102-page outline treatise on the bases, principles, and techniques of the identification of firearms by analysis and comparison of the "signatures" left on bullets and cartridge cases in the process of firing. Excellent photographic illustrations accompany the discussion of such topics as types of propellants, firearms, and am-

[1] Commanding Officer, Ballistic Bureau, New York Police Department.

NOTE: Readers of MECHANICAL ENGINEERING will recall two articles on markings on bullets and shells fired from small arms that appeared in the February and December, 1930, issues. The author of these articles, Charles O. Gunther, in collaboration with Jack D. Gunther, has completed the work reported in 1930 and the book under review is the result of it. Because of the importance of the subject discussed, and the layman's unfamiliarity with it, an attempt has been made to secure several opinions that represent different points of view. The reviews are by the commanding officer of the Ballistics Bureau of the New York Police Department, in which more than 3000 firearms are tested and 800 shooting cases are handled annually, a lawyer and teacher of law at the Yale School of Law, and the chief of the Identification Laboratory, Bureau of Standards.—EDITOR.

[2] Yale School of Law, New Haven, Conn.

munition, rifling, microscopes, tool marks, class and accidental characteristics, classification, motion of a bullet through the bore, manufacture of pistol barrels, recovery of test bullets, analysis of signatures, problems of identification, and solution of problems. Emphasized throughout is the importance of skilled interpretation as well as of skilled observation and perception of data, for "The art of identification concerns reasoning with respect to similarities and differences. It is found that there are differences in the signatures of a particular firearm and that similarities exist in the signatures of different firearms."

In the light of the foregoing the authors then embark upon a 143-page analysis of the Sacco-Vanzetti case, persuaded thereto by the "abundance of interesting material relating to the identification of firearms" afforded in its record, and by their own judgment that in view of the weakness of all other evidence in the case "The identification of Sacco's gun was the natural determinant of the guilt or innocence of Sacco." The firearms, exhibits, the testimony at the trial, the summations of counsel, Judge Thayer's charge to the jury, the motions for new trial, and Judge Thayer's decision are all reviewed in detail in so far as they touch on the questions at hand. Their conclusion is that both judge and jury at the trial were misled by the expert testimony, and that what "might have been the most indubitable evidence was in fact rendered more than useless by the bungling of the experts." This makes up chapter 2.

The final chapter, entitled "Analysis of the Authorities on Firearms Identification," is prefaced by the observation that while methods of proof requisite to the identification of a firearm by its "signature" have but recently become of sufficient reliability to merit judicial sanction, courts during the past half-century have often been confronted with the question of admitting in evidence testimony and objects offered as proof that the victim of a crime had been struck by a bullet or pellet discharged from a particular firearm. As is scarcely surprising, many of the rulings in the cases reviewed are found to have been erroneous when tested by present understanding of the highly technical considerations involved. Juries have on occasion been permitted to draw their own inferences from the markings on firearms exhibits without the indispensable aid of expert interpretive opinions. Experts have been allowed to testify who employed unreliable methods of proof predicated upon incomplete data. Trial counsel have often failed to expose defects in the "ballistics" evidence of the adversary or to adequately present what their own experts had to offer. But as the authors point out, "there was no helpful written material on the subject prior to the last few years," and many witnesses may be criticized "for having misled the courts as to the extent of the development of the extent of firearms identification."

Emerging from this record, in brief, are those same troublesome frailties and sources of prejudice notorious in the employment of expert opinion generally in the legal process. That these recently developed techniques of firearms identification, handled in a trained, scrupulous, and intelligent fashion, offer a reliable contribution to the problem of proof in homicide cases, is unhesitatingly affirmed by the authors. But they do not seek to minimize the limitations inherent in the technique. "In some cases the insufficiency or condition of the data may preclude any reliable conclusion. In others, the observable data may only support the conclusion that the bullet or cartridge case might have been fired in a particular firearm." Experts are accordingly urged not to hesitate to qualify their opinions and to set forth carefully and frankly the limitations inherent in the data of particular cases. Turning to the courts: ". . . the tendency is to allow experts to qualify easily upon a relatively insignificant representation of specialized experience. . ." Higher standards in this respect are advocated, with the following suggestions: ". . . the only way by which a working knowledge can be acquired at present is by individual research along scientific lines, under the direction of a trained investigator. The vital element in this field of identification is *scientific judgment* which can be gained only through the performance of actual experiments. . . The expert must be skilled in the use of the comparison microscope. . . Surely a competent expert in firearms identification will not have a great deal of time to devote to other fields."

For the benefit of counsel, in addition to the general initiation into the subject afforded by chapter 1 and the exercises in its application in the form of analyses of trial transcripts contained in chapters 2 and 3, the authors have also included a comprehensive set of questions designed to test the ability of a witness and to bring out his familiarity with and knowledge in this field. All in all, this very usable manual is a worth-while contribution to the literature of police science and of that branch of the law of evidence concerned with expert opinion.

REVIEWED BY WILMER SOUDER[3]

The first hundred pages of the book are interesting and will be found to contain much material of value to the reader. The remainder of the book gives extracts from court records and offers comments on expert testimony. These records and comments are valuable to the expert who is interested in improving his exhibits and methods of presenting evidence.

No reference was discovered crediting foreign workers and laboratories such as (the late) Derome, Söderman and Locard, with success in this field. References to United States workers such as Crossman, Gill, May, O'Neil, Vollmer, and many others would have strengthened the appeal in the minds of many readers.

The student striving to master this science will find little aid or advice in the selection of types of lenses, illuminating devices, the use of diaphrams, filters, screens, and reflectors. Fig. 22 shows a comparison microscope but does not show the more recent development in this instrument and equipment. The difficulties and pitfalls encountered in viewing and photographing bullets, primers, and shells are not explained. The student is given practically no data on trade-marks, specifications for bore diameters, land widths, ballistic tables, etc., for the large number of American and foreign arms such as are given (in French) by the late Dr. Derome, of Montreal, who gave more than 100 pages to these data.

The blurring or overlapping of test and body bullets (and primers) in the photographs (resulting from a lack of sharp focus on the edge of the prisms of the combining eye-piece) do not give the nearest approach to unbiased evidence. This is well illustrated in Figs. 128 and 132. To many jurors or judges there will appear to be more evidence of agreement in Fig. 132 for the two primers fired in different guns than in Fig. 128 for the two bullets fired through the same gun. The depths of the landmarks on this same pair of bullets (shown again in Fig. 127) as portrayed along the corresponding ogives, may puzzle even experts in bullet identification.

There are frequent references to identification of handwriting. The attempt to advance the science of firearms identification under the assumption of similar laws is at times carried too far. For example, note the two statements: "In some respects a firearm's signature is like a personal signature. If two personal signatures are found to coincide exactly

[3] Chief, Identification Laboratory, Bureau of Standards, Washington, D. C.

in every detail when superimposed, it indicates that probably one of the signatures is a forgery." If such assumptions are generally accepted, opposing counsel could punish some of our best experts who have shown (so far as many jurors are able to judge) exhibits of test and fatal bullets which do coincide exactly.

The book should be revised with the thought of assisting students in this field. The illustrations should be selected with the purpose of showing to those who study them carefully, that confusions need not arise in interpreting this type of evidence.

Diesel Engines

DIESEL ENGINES. By J. W. Anderson. McGraw-Hill Book Company, New York, 1935. Cloth, 6 × 9 in., 491 pp., 384 figs., $5.

REVIEWED BY H. SCHRECK[4]

THIS book is a survey of the various makes of Diesel engines on the market today. It is profusely illustrated and enumerates, point by point, the characteristics of the engines by means of references to the various engines illustrated. In this way it will serve as an excellent reference book on Diesel engines. Much information otherwise available only in many textbooks and journals has been collected with great care by the author and is presented with proper classification.

The book will serve a good purpose in familiarizing its readers with the various types of engines. However, when a reading of the book is completed, neither the prospective buyer of Diesel engines nor the engineer who seeks more specific information on any particular point in this field will know which way to turn. Four pages and a half are devoted to the selection of an engine, and eleven pages to operation and maintenance, of which as much as one page is devoted to operating difficulties. On the other hand, the jacket of the book states—that it explains "operation and maintenance, performance, and selection . . . ." It is hardly possible to do justice to these subjects in such a limited space since each one would fill a book by itself, hence the omission of these particular chapters, or the direction of attention to them, incomplete as they are, might have saved the publishers some disappointed readers.

All through the book the various makes of engines have been discussed from the viewpoint of a catalog. The specific features of each engine are mentioned but the author refrains from making suggestions and from offering his own conclusions.

In many cases, in connection with the various makes of engines illustrated, the author omits to mention bore and stroke and horsepower of the engine, where he might have given the reader some idea of the approximate dimensions of each particular design.

The subject of the combustion chamber is an important one today. As a matter of fact in high-speed Diesel engines, such as those of the automotive type, it is the paramount factor upon which the future of this type of engine depends, yet the reader finds little enlightenment upon this point. The various types of chambers are enumerated; but which engines require an auxiliary chamber and why? In order that the reader might get some more definite conception of the various types of chambers and their modifications, it would help much if the author had subdivided them into the principal groups, such as open combustion space, turbulence chamber (called antechamber), precombustion chamber, and air-cell chamber. An analysis of the advantages, operating results, and difficulties with each type of combustion chamber would have been worth while.

Only seventeen pages are devoted to the chapter on fuels and fuel systems, a subject which is equally important to the operator of an engine and to the man who is about to select an engine for his particular needs or application, most of all in the small-size, high-speed Diesel engine. The author says little about the necessary characteristics of the fuel in regard to ignition delay, which is an important factor in satisfactory operation of Diesel engines, particularly the high-speed engines described in the chapter on the combustion chamber. How many readers know about Diesel index and what it means? The author speaks of the Hesselman engine as being less sensitive to the ignition qualities, but what about the necessary characteristics or limitations of various fuels for this and other engines in regard to Diesel knock? Ignition delay is an important point in the choice of a suitable fuel oil and in connection with the type of combustion chamber in any engine under consideration.

One cannot help but appreciate the efforts expended in collecting the material covered in this book and it should make good reading matter for anybody interested in Diesel engines from the commercial point of view.

[4] Ingersoll-Rand Co., Painted Post, N. Y. Mem. A.S.M.E.

Books Received in Library

ANNUAIRE DU COMMERCE INTERNATIONAL, L'ANNUAIRE BLEU. Encyclopédie économique universelle établie sous la direction de M. Armand Megglé, 1935. Administration, 77 Rue des Saints-Pères, Paris. Cloth, 9 × 11 in., 1549 pp., maps, illus. This annual is an economic encyclopedia of world commerce, prepared with special reference to the French export trade. The first section contains an account of the principal industries of France with information on the importance of each. the principal producing centers, the exports and directory of the principal producers, together with practical information about exporting. Succeeding sections describe the foreign commerce, government, tariffs, communications, products, etc., of the French colonies and foreign countries.

DIE AUSSICHTEN VON ZWANGLAUFKESSELN, eine kritische Betrachtung des derzeitigen Standes im Bau und Betrieb von Röhrendampferzeugern. By F. Münzinger. Julius Springer, Berlin, 1935. Paper, 6 × 9 in., 16 pp., diagrams, charts, tables, 5.80 rm. In this work which is an expansion of an address delivered at the 1935 annual meeting of the Verein deutscher Ingenieure, the author reviews critically the present position of multitubular-boiler design and construction. Particularly he considers the possibilities connected with the use of various methods for increasing the circulation of water, and the use of higher pressures, and discusses their advantages and disadvantages.

A BIBLIOGRAPHY ON THE CUTTING OF METALS. Part 2. By O. W. Boston. Edwards Brothers, Ann Arbor, Michigan, 1935. Cloth, 5 × 8 in., 202 pp., $2.50. This bibliography continues one by the same author which appeared in 1930. It contains 1257 references to articles on metal-cutting tools, materials cutting, and cutting fluids, chiefly published between 1929 and 1934. The references are annotated for the most part, and are indexed by subjects and authors.

CAST METALS HANDBOOK, 1935 edition. Published by American Foundrymen's Association, Chicago. Cloth, 6 × 9 in., 424 pp., illus., diagrams, charts, tables, $4. This handbook, sponsored by the American Foundrymen's Association, is designed to provide designers and users of castings with up-to-date, correct information on the properties and applications of cast metals. The first section consists of recommendations to designers of castings, the second of recommendations to buyers. Succeeding sections give information on the properties and uses of cast iron, malleable cast iron, cast steel, and the principal nonferrous casting alloys.

LA CÉMENTATION DES PRODUITS MÉTALLURGIQUES ET SA GÉNÉRALISATION, 2 volumes. By L. Guillet. Dunod, Paris, 1935. Cloth, 6 × 10 in., illus., diagrams, charts, tables, vol. 1, 373 pp., 120 fr; vol. 2, 465 pp., 145 fr. These two volumes provide a survey of the theory and practice of cementation. Volume one is devoted to the carburizing of ordinary and special steels. Volume two discusses nitriding, calorizing, sherardizing, the cementation of ferrous products with other metals, the cementation of nonferrous metals; and the manufacture of malleable iron. The treatise discusses these processes in a detailed manner, and is unusually comprehensive and complete.

COAL THROUGH THE AGES. (Seeley W. Mudd Fund.) By H. N. Eavenson. American Institute of Mining and Metallurgical Engineers, New York, 1935. Cloth, 5 × 8 in., 123 pp., illus., charts, tables, $1.50 to nonmembers, $1 to members. In this volume the development of the coal industry and its influence upon civilization are presented in three addresses: coal through the ages; coal in our national economy; and mineral fuels and civilization.

DAVISON'S CORDAGE, TWINE AND DUCK TRADE. Twenty-seventh edition. 1934–1935. Davison Publishing Co., New York, 1935. Cloth, 5 × 8 in., 264 pp., $3. This directory lists manufacturers and dealers connected with the cordage, twine, duck, canvas, and linen trades in the United States and Canada. Manufacturers are listed geographically and by products. Information is given on capitalization, officers, equipment, etc.

DAVISON'S TEXTILE BLUE BOOK. (Handy edition.) United States, Canada, and Mexico. 70th year, July, 1935, to July, 1936. Davison Publishing Co., New York, 1935. Cloth, 5 × 8 in., 1300 pp., maps, illus., $5. The Blue Book provides a comprehensive directory of the textile industry. The names and addresses of textile mills, commission merchants, dyers, finishers, and dealers in textiles and textile materials in North America are listed. Information as to size, officials, equipment, and products of mills is added. Careful indexes are included, as well as maps showing the locations of mills.

DEUTSCHES MUSEUM, ABHANDLUNGEN UND BERICHTE, Jg. 7, Heft 2. Wald und Mensch im technischen Zeitalter, by E. Diesel. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 42 pp., diagrams, 0.90 rm. The value of German forests to the nation and the social and economic influences which they exert upon national life are described briefly. The bulletin is intended for the general reader.

DIESEL ENGINES. By J. W. Anderson. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 491 pp., illus., diagrams, charts, tables, $5. This treatise describes the various types of engines in use in America, with some European examples as well. The types are classified according to their applications, in a useful, practical way. Theory and design are discussed, the reasons for the different types explained, and attention is given to installation, operation, performance, and cost of operation. Selection is considered in a final chapter. The book gives a picture of the Diesel engine in the United States today.

Eidgenössische Materialprüfungsanstalt an der E.T.H. in Zürich (Laboratoire Fédéral d'Essai des Matériaux annexé a l'École Polytechnique Fédérale a Zürich) Bericht Nr. 91. BEMERKUNGEN ZUR WASSERUNTERSUCHUNG UND WASSERREINIGUNG IM KESSELBETRIEB, by P. Schläpfer. Zürich, February, 1935. Paper, 8 × 12 in., 11 pp., tables. This lecture discusses the minimum qualities of water for various kinds of boilers, the interpretation of water analyses for feedwater control, the most appropriate methods of purification, etc. The lecture gives a practical survey of current methods.

Eidgenössische Materialprüfungsanstalt an der E.T.H. in Zürich (Laboratoire Fédéral d'Essai des Matériaux annexé a l'École Polytechnique Fédérale a Zürich) Bericht Nr. 93. ZUR WASSERREINIGUNG MIT TRINATRIUMPHOSPHAT, by P. Schläpfer. July, 1935; Zürich. Paper, 8 × 12 in., 9 pp., charts, tables. The problems investigated in this study were the comparative values of soda and various commercial brands of trisodium phosphate as water softeners, the degree of softness attainable with the latter, and the detection of phosphoric acid in boiler water.

Eidgenössische Materialprüfungsanstalt an der E.T.H. in Zürich (Laboratoire Fédéral d'Essai des Matériaux annexé a l'École Polytechnique Fédérale a Zürich). Diskussionsbericht Nr. 87. FESTIGKEITSEIGENSCHAFTEN DER STÄHLE BEI HOHEN TEMPERATUREN. Zürich, April, 1934. Paper, 8 × 12 in., 51 pp., illus., diagrams, charts, tables. This pamphlet presents the results of an extensive investigation of the behavior of steels at high temperatures, undertaken to establish a theory of deformation. The components of the total deformation were established and the creep limit investigated. The work was carried out at the Federal Testing Laboratory, Zurich. The report is in German, with a summary in English.

ELEMENTS OF MACHINE DESIGN. By D. S. Kimball and J. H. Barr. Third edition. John Wiley & Sons, Inc., New York, 1935. Cloth, 6 × 9 in., 476 pp., diagrams, charts, tables, $4. This textbook on the fundamental principles of machine design has been in use for twenty-five years and is too well known to call for extended comment. No radical changes have been made in the third edition, but each topic has been brought up to date, new subject matter has been added where necessary, and some obsolete sections eliminated.

FINANCIAL INCENTIVES, a study of methods for stimulating achievement in industry. (National Industrial Conference Board Studies, no. 217.) National Industrial Conference Board, New York, 1935. Paper, 6 × 9 in., 47 pp., tables, $1.50. Conditions during the past five years have subjected wage-incentive plans to a severe test. Primarily intended to increase output, they have been obliged to function under conditions of decreased production, increased wage rates and reduced hours. This study by the National Industrial Conference Board reviews the experience of industrial concerns in operating these plans under the new conditions, describes the changes that have been necessary, and discusses the probable future rôle of incentives.

FINISHING METAL PRODUCTS. By H. R. Simonds. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 337 pp., illus., diagrams, charts, tables, $3.50. This book aims to give the manufacturer of metal goods a survey of the methods of finishing his products, in order to protect them or make them more attractive. The commercial advantages of good appearance, the preparation of metals for finishes, polishing, plating, painting, and other methods of finishing are described. Parts of the book have appeared in *The Iron Age*.

FORSCHUNGSHEFT 374. ZÜNDUNG UND FLAMMENBILDUNG BEI DER DIESEL-BRENNSTOFF-EINSPRITZUNG. By O. Holfelder. V.D.I. Verlag, Berlin, 1935. Paper, 8 × 12 in., 25 pp., illus., diagrams, charts, tables, 5 rm. Presents the results of an extended study of the phenomena of ignition and combustion of sprayed fuels in the Diesel engine. The results are the first, it is claimed, which can be accepted as comparable to actual operating conditions.

GREAT BRITAIN, Department of Scientific and Industrial Research. INDEX TO THE LITERATURE OF FOOD INVESTIGATION, Vol. 6, No. 1, March, 1934. Compiled by A. E. Glennie and G. Davies. His Majesty's Stationery Office, London; obtainable from British Library of Information, N. Y. 1935. Paper, 6 × 10 in., 309 pp., 5s. This useful addition to the semi-annual index covers approximately one hundred periodicals, indexing and abstracting the literature pertaining to the storage and preservation of animal and vegetable foods. The material on cold storage, refrigeration, and air conditioning has special interest for engineers. An introduction reviews developments during 1932–1933.

HANDBOOK OF THE COLLECTIONS ILLUSTRATING AERONAUTICS—I. HEAVIER-THAN-AIR AIRCRAFT. Science Museum, Board of Education. By J. B. Davy. His Majesty's Stationery Office, London, 1935. Paper, 6 × 10 in., 125 pp., illus., 2s 6d. This attractive handbook offers a concise account of the history and development of heavier-than-air aircraft, from the time of Leonardo da Vinci to the present day. The book is well illustrated with contemporary prints and photographs. It has been written with special reference to the aeronautical collection at the Science Museum, London, and includes an annotated catalog of the relevant exhibits there.

(A) HISTORY OF SCIENCE, TECHNOLOGY, AND PHILOSOPHY in the Sixteenth and Seventeenth Centuries. By A. Wolf. The Macmillan Co., New York, 1935. Cloth, 6 × 10 in., 692 pp., illus., diagrams, charts, tables, $7. This is an unusually interesting and attractive work, as well as one of great value. It gives an account of the achievements in all branches of "natural" knowledge and technology during the centuries under review, with biographies of the important workers. The illustrations are attractive and add to the interest of the reader, and the volume is well supplied with references to the sources. The work is eminently readable and affords the best extant approach to the history of modern science.

International Conference on Physics, London, 1934. International Union of Pure and Applied Physics. REPORTS ON SYMBOLS, UNITS, AND NOMENCLATURE, published by the Physical Society, London; printed at the University Press, Cambridge, England, 1935. Cloth, 7 × 10 in., 40 pp., diagrams, tables, $1.20. The reports approved by the International Union of Physics at its 1934 meeting included recommendations on the standard thermal unit, electromagnetic units, thermodynamic symbols, and on future work of the committee on symbols, units, and nomenclature. These reports are given here in full, together with a paper on the definitions of the magnetic units, by H. Abraham, and one on the force between two elements of current, by P. Vigoureux.

LE MACCHINE TERMICHE. Part 2. Le Turbine e le Motrici Alternative a Vapore. By M. Medici. Padova, Italy, (CEDAM) Casa Editrice Dott. Antonio Milani, 1935. Cloth, 7 × 10 in., 235 pp., illus., diagrams, charts, tables, 28 lire. The second part of Professor Medici's treatise on heat engines discusses

the theory and design of steam turbines and reciprocating engines. The former of these is considered first and at greater length. The theory of the turbine, energy losses, regulation, design, and the various types of turbines are successively discussed in a practical, modern way. The discussion of alternating engines occupies but a small part of the book.

MATERIALS TESTING MACHINES. By C. H. Gibbons. Instruments Publishing Co., Pittsburgh, 1935. Cloth, 5 × 8 in., 89 pp., illus., tables, $2. This account of the development of testing machines traces their history from the experiments of Galileo to the present day. The author is especially interested in the tension-compression-transverse group of machines and traces their history carefully. Many interesting illustrations of important machines are included.

METALLIC ARC WELDING. By H. Harris. Longmans, Green & Co., New York; Edward Arnold & Co., London, 1935. Cloth, 6 × 10 in., 199 pp., illus., diagrams, charts, tables, $6. An excellent, readable survey of arc welding, intended especially to call its usefulness to the attention of potential users of the process. The process and its equipment are described, methods of testing welds are reviewed and the influence of oxygen and nitrogen discussed. Chapters are devoted to the aging of weld metal and the welding of steels of various types and of copper and nickel and their alloys. Finally, the principal applications of arc welding are considered.

PHYSICS. By E. Hausmann and E. P. Slack. D. Van Nostrand Co., New York, 1935. Cloth, 6 × 9 in., 776 pp., illus., diagrams, charts, tables, $4. This text offers a thorough course in the essentials of physics for college students preparing for scientific or engineering careers. It aims to give a gradual, logical approach to the subject, to develop and illustrate clearly the fundamental concepts, and to afford a mastery of the basic principles.

RUBBER, PHYSICAL and CHEMICAL PROPERTIES. By T. R. Dawson and B. D. Porritt. Research Association of British Rubber Manufacturers, Croydon, England, 1935. Cloth, 9 × 11 in., 700 pp., diagrams, charts, tables, 45s. A reference book for manufacturers and users of rubber, produced cooperatively by the Rubber Growers' Association and the Research Association of British Rubber Manufacturers. It summarizes in systematic fashion, in detail, the available data upon the physical and chemical properties of rubber, collected from all publications prior to March, 1934. Other features are a section on analysis and testing, an extensive index of specifications for rubber goods, a glossary, a list of associations, and a lengthy bibliography. The work will be indispensable to engineers, physicists, and chemists interested in rubber.

SCHWEIZ. VERBAND FÜR DIE MATERIALPRÜFUNGEN DER TECHNIK. (ASSOCIATION SUISSE POUR L'ESSAI DES MATÉRIAUX.) Diskussionsbericht Nr. 32 (Bericht Nr. 88 der Eidg. Materialprüfungsanstalt). MITTEILUNGEN ÜBER SCHNELLDREHSTÄHLE. Zürich, December, 1934. Paper, 8 × 12 in., 35 pp., illus., diagrams, charts, tables. The structure, heat-treatment, and composition of high-speed steels are concisely reviewed in this address by the director of the Deutsche Edelstahlwerke, delivered at a meeting of the Swiss Association for Testing Materials.

STRENGTH AND FLEXIBILITY OF CORRUGATED AND CREASED-BEND PIPING, a dissertation submitted to the advisory board of the school of engineering of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Engineering. By R. L. Dennison. Reprinted from the *Journal of the American Society of Naval Engineers*, Washington. Vol. 47, No. 3, August, 1935. Paper, 6 × 9 in., pp. 343–432, illus., diagrams, charts, tables, $1. This dissertation gives the results of an extensive series of tests made at the U. S. Naval Experimental Station to throw light upon some problems in the design of steam piping. The relationship between the load and deflection with corrugated and creased-bend pipes, and the endurance of the pipes under cyclic stresses were investigated; methods were developed for measuring the strains induced under load and interpreting their significance; and values derived for safe working stresses.

STRENGTH OF MATERIALS. By E. R. Maurer and M. O. Withey. Second edition. John Wiley & Sons, Inc., New York, 1935. Cloth, 6 × 9 in., 382 pp., illus., diagrams, charts, tables, $3.50. The principal change in this revision is in the chapter on columns, which now conforms to the recommendations of the American Society of Civil Engineers. An article on welded joints has been added and the articles on axial impact and tubes under external pressure have been modified, as have various tables. New problems have been added.

1935 SUPPLEMENT TO BOOK OF A.S.T.M. STANDARDS. American Society for Testing Materials, Philadelphia, 1935. Paper, 6 × 9 in., 208 pp., diagrams, charts, tables, $1.50 (to members $1). This pamphlet is a second supplement to the 1933 Book of A.S.T.M. Standards, containing thirty-six standards which were adopted or revised in September, 1935. Of these, one-half are new standards. The supplement brings the 1933 issue and the first supplement up to date.

TASCHENBUCH FÜR DEN MASCHINENBAU. Two Vols. Edited by H. Dubbel. Sixth edition. Julius Springer, Berlin, 1935. Cloth 5 × 8 in., diagrams, charts, tables, 22.50 rm.; vol. 1, 818 pp.; vol. 2, 902 pp. The sixth edition of this well-known handbook for mechanical engineers shows the qualities that have made previous editions popular—careful selection of material and clear presentation, with attention to practical needs. A new section has been added, on automobiles, and other sections have been revised.

TASCHENBUCH FÜR SCHIFFSINGENIEURE UND SEEMASCHINISTEN. By E. Ludwig. R. Oldenbourg, Munich and Berlin, 1935. Cloth, 4 × 7 in., 633 pp., illus., diagrams, charts, tables, 12 rm. The new edition of this pocketbook for marine engineers has been thoroughly revised. Material upon new developments has replaced older material and some new sections are introduced, notably one on coal-dust firing. The book covers the construction and operation of marine boilers, engines and turbines, and their auxiliaries, auxiliary mechanical equipment, electrical equipment, and instruments. The necessary tables of mathematical and physical data are included.

LES TURBINES À VAPEUR et à Combustion interne. By P. Lorain. Librairie de l'Enseignement Technique, Paris, 1935. Paper, 7 × 10 in., 688 pp., diagrams, charts, tables, 160 frs. Turbine theory and construction are presented for students, designers, and engineers in this volume, which endeavors to present the essentials of modern practice within moderate limits of space. Starting with a chapter on thermodynamic fundamentals, the author treats of the flow of elastic fluids, the theory of the perfect turbine, losses, the working of the actual turbine, the influence of operating conditions on steam consumption, and regulation. Other chapters consider the construction of the principal organs, marine turbines, high-pressure turbines, and present tendencies in design. A final chapter is devoted to gas turbines.

UNSERE VERBRAUCHSGÜTER UND IHRE HERSTELLUNG. By K. W. Geisler. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 177 pp., diagrams, tables, 3.90 rm. This is a concise, readable account of the raw materials and processes used in the manufacture of the principal classes of consumer goods; metals, claywares, paper, fuels, foods, dyes, acids, etc.

WÄRMETECHNISCHE RECHNUNGEN FÜR BAU UND BETRIEB VON OFEN. By W. Heiligenstaedt. Edited by Wärmestelle Düsseldorf des Vereins deutscher Eisenhüttenleute. Verlag Stahleisen, Düsseldorf, 1935. Cloth, 6 × 8 in., 186 pp., charts, diagrams, tables, 11.50 rm.; paper, 10.35 rm. This book discusses the thermal calculations required by the designer and operator of industrial furnaces, from a thoroughly practical point of view. Little space is given to the theories, but their results, so far as they are of practical use, are expressed in rules for calculating, in numerical tables and formulas. Heat balance, combustion, heat transfer and conduction and heating effect are considered, and a chapter is devoted to heat exchange in recuperators and regenerators.

WAS MUSS DER INGENIEUR VOM MESSING WISSEN? Herausgegeben vom Deutschen Kupfer-Institut e.V. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 134 pp., illus., diagrams, charts, 2.50 rm. This concise, practical presentation of the properties, working, and uses of brass has been prepared by the German Copper Institute. After a brief survey of the preparation of brass, its crystalline structure is described, the influence of other metals is explained, and the mechanical and physical properties, heat treatment and methods of joining are discussed. A second section is devoted to the casting and working of brass and the properties of wire, tubing, shapes, etc. The German standard specifications that apply to the metal are included.

WIRKUNG VON DRUCKVORSPANNUNGEN AUF DIE DAUERFESTIGKEIT METALLISCHER WERKSTOFFE. By G. Seeger. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 56 pp., illus., diagrams, charts, tables, 5 rm. The influence of compressive stresses upon the fatigue resistance of metals is discussed in this report, which describes experiments carried out at the Stuttgart Technical High School.

ENGINEERING RADIOGRAPHY, by V. E. Pullin, reviewed in MECHANICAL ENGINEERING, December, 1934, p. 765. Published by G. Bell & Sons, Ltd., London; now handled in United States by The Engineers Book Shop, New York.

WHAT'S GOING ON

This Month's Authors

IN the automobile industry generally great advances in surface finishes have resulted in lower maintenance costs to the car owner, and have greatly reduced the length of the run-in period in which new cars were formerly nursed through the first 500 miles. J. E. KLINE, who is chief engineer of the Hutto Machine Division, Carborundum Company, writes this month on desired characters of surface finishes in machine work.

HERMAN VAN TONGEREN, who describes a dust collector in which attention has been paid to the effect of the double-eddy current, is a graduate of Delft University, and is well known in England and on the Continent for his work in aerodynamics.

J. F. DOWNIE SMITH, associate-member, A.S.M.E., instructor in mechanical engineering, Harvard Graduate School of Engineering, was graduated from the Royal Technical College and from Glasgow University in 1923, after which he came to this country. In addition to experience in design, Mr. Smith taught at Georgia School of Technology and Virginia Polytechnic Institute before going to Harvard. SYDNEY STEELE, at present a chemical engineer at the Niagara Falls plant of E. I. du Pont de Nemours & Co., has studied at the University of Cambridge, England, The Johns Hopkins University, and Harvard University.

The co-authors of this month's paper on the water-cooled stoker represent the manufacturer of the stoker and the purchaser in whose plant the developmental work was carried on. JOSEPH S. BENNETT, member, A.S.M.E., mechanical engineer, American Engineering Company, Philadelphia, with whom he has been associated since the War, has been identified in the United States, Canada, Great Britain, and the Continent with developments in modern rotary ash-discharge stokers and water-cooled furnaces. CHARLES J. HERBECK, chief engineer of the Cedar Rapids Station, Iowa Electric Light & Power Co., has a twenty-five year experience on power plants. He has devoted much time to the problem of burning Western coals in underfeed stokers.

F. E. ARMSTRONG is a member of the department of economics and social science, Massachusetts Institute of Technology which he entered in 1916 and which he has served as professor of political economy since 1926. He has been identified with the development of the course in engineering administration at M.I.T., and in corporate organization and finance, and public utilities and investments.

ARSHAG G. SOLAKIAN, lecturer in mechanical engineering, Columbia University, is a native of Turkey and was graduated, with degrees in civil and mechanical engineering departments, from Robert College, Constantinople. From 1917 to 1930 he served on the engineering teaching staff at Robert College in courses in structural engineering and materials testing. In 1930 he studied photoelasticity under E. G. Coker, University College, London.

I. H. FULLMER, member, A.S.M.E., is associate physicist in the National Bureau of Standards, U. S. Department of Commerce. He has been with the gage section of the Bureau, with but a brief interruption in 1920–1921, since he was graduated from the Case School of Applied Science, in 1917.

ROBERT W. ANGUS, member, A.S.M.E., is professor of mechanical engineering at the University of Toronto. He has made hydraulics a specialty, and his translation of Kreitner's work on water hammer brings this paper within the reach of engineers who cannot read German.

PARKER H. DAGGETT, dean of the College of Engineering, Rutgers University, is a member of the Engineers' Council for Professional Development. He was a member of the North Carolina State Board of Education, 1921–1929; from 1922 to 1923 he served as secretary of the National Council of State Boards of Engineering Examiners, and from 1925–1926 as president.

A.S.M.E. Council Actions, St. Louis, Mo., Oct. 11–12

AT a meeting of the Council of The American Society of Mechanical Engineers, held in St. Louis, Mo., October 11 and 12, for the principal purpose of discussing basic Society policies, the following actions were of general interest.

ADMISSION PROCEDURE

Consideration was given to the procedure of scrutinizing candidates for admission to the Society and the view was expressed that its gradual intensification was desirable, with special emphasis on quality rather than quantity of membership.

COUNCIL ORGANIZATION

The Committee on Policies and Budget, Harry R. Westcott, chairman, reported proposals relating to the responsibilities of individual members of the Council in an organization plan designed to create a more effective contact between members and the Council. These recommendations were approved in principle and the president was authorized to proceed with the scheme within the limits of the present budget. The recommendations follow:

1 That the Council delegate the senior member in point of years on the Council from each of the seven geographical groups of the Society to act as the president's representative within that group.

2 That each member of the Council so delegated to represent the president in a geographical group shall be clothed with the president's prerogative to act as the leader of the members and of the local sections and student branches within his group to the end that the Society interests of the members may be enhanced and the activities and progress of the local sections and student branches be encouraged.

3 That to accomplish those things referred to herein, those members of the Council so delegated be requested by the Council to visit the local sections and the student branches within their respective groups when convenient and to confer with members and to discuss Society affairs with them.

4 That an appropriation be made in the budget for travel allowance for the geographical councillors to visit the local sections and attend the group conferences.

5 That the members, local sections, and student branches within each group be requested and encouraged to cooperate fully with the member of the Council so delegated to the end that he may most effectively function as herein recommended.

6 That this member of the Council advise the Council and the officers of the Society regarding the point of view of the members, the local sections, and the student branches within his group to the end that the Council and the officers of the Society may be so informed as to permit them best to perform their duties.

7 That this member of the Council advise the members within his group regarding the acts of the Council and its aims, objectives, and policies, with the reasons therefor.

8 That the seven councillors so delegated meet with the president as a group on the occasion of each Council meeting, to exchange views.

9 That the Council members so delegated should attend the group conferences of local sections delegates of his territory.

10 That the Council members so delegated should collectively attend the local sections delegates conference on the occasion of the Annual Meeting.

11 That the Nominating Committee be advised regarding this recommendation with the hope that this Committee will give consideration thereto when making nominations for membership on the Council.

12 That nothing herein shall be construed as infringing upon, curtailing, or modifying the obligations, duties, and prerogatives of the Committee on Local Sections as it has heretofore functioned, or the local sections delegates conference.

DIVISIONS AND PUBLICATIONS REPORT

W. A. Shoudy, for the Committee on Professional Divisions, and S. W. Dudley, for the Committee on Publications, reported on plans under consideration. Inasmuch as they are still under discussion by the committees and will be subject to continuing study and future consideration by various groups, no action was taken.

LOCAL SECTIONS MEETINGS

W. L. Dudley, for the Committee on Local Sections, presented a tabulation of subjects

and speakers, as reported to Society headquarters between Sept. 1, 1934, and July 1, 1935. He reported that substantial improvement was possible in section programs, and urged that the Council members in each area exert leadership to this end. Committees on Professional Divisions and on Meetings and Program reported their interest in assisting the suggested improvement.

REGISTRATION OF ENGINEERS

The Committee on Registration Policy, appointed at the Cincinnati meeting of Council, June 18, 1935, consisting of James H. Herron, chairman, John A. Hunter, and James M. Todd, reported recommendations that were adopted by the Council.

The committee recommended that the Council authorize the president to appoint a standing committee on registration to be composed of five members with a three-year term of office.

PRIVILEGES OF NONMEMBERS

At the suggestion of the Committee on Policies and Budget the Council voted to approve the general policy of restricting privileges of the Society to members and to accept, for reference to the sections' conferences and the standing committees interested, the following suggestions for carrying out this policy:

Nonmembers shall be permitted to attend meetings of the Society or its divisions only on the payment of a fee.

Nonmembers shall be permitted to present papers before the national meeting of the Society only upon the recommendation of the Committee on Meetings and Program and the invitation of the Council.

Nonmembers shall be permitted to present papers before a divisional or sectional meeting only upon the invitation of the proper executive committee.

Nonmembers shall not be permitted to preside at any meeting of the Society or any division or section.

The only exceptions shall be in regard to members of bodies participating with the Society in a joint meeting.

SIX-YEAR JUNIOR DUES

The matter of compulsory increase in Junior member dues after six years of membership was referred to sections conferences with a request that opinions relating to it be transmitted to the Committee on Policies and Budget, for report to the Council.

AMENDMENTS TO BY-LAWS

It was voted to adopt the following wording of Article B8, Par. 23, of the By-Laws, as presented to the Council in June, 1935:

The Standing Committee, designated as the Board of Honors and Awards, shall, under the direction of the Council, have supervision of the awards of the Society as detailed in the Rules or prescribed by the Council. Recommendations for representatives on joint bodies of award shall be made to the Council by this Board. The Board shall consist of five members, and the term of one member shall expire at the close of each Annual Meeting.

Article B14, Par. 13 was amended to read as follows:

Income from initiation fees shall not be used for current expenses. At the close of each fiscal year, unless the Council then orders otherwise, this income shall be added to surplus.

AWARDS FOR 1935

The Board of Honors and Awards, W. L. Batt, chairman, presented the following recommendations, which were approved by the Council, for awards for 1935:

A.S.M.E. Medal: Charles T. Main.

Worcester Reed Warner Medal: S. Timoshenko, "for his contributions to the theory of the design of elastic structures and the treatment of dynamics of moving machinery."

Melville Medal: O. R. Wikander. for his paper, "Draft-Gear Action in Long Trains." (See A.S.M.E. Transactions, August, 1935, paper RR-57-1, pp. 317–334.)

Undergraduate Student Award: Robert W. Beal, of Oregon State College, for his paper, "Do Lubricating Oils Wear Out?"

Postgraduate Student Award: Charles P. Bacha, of Rutgers University, for his paper, "The Behavior of Metals Subjected to Combined Stress."

Junior Award: S. J. Mikina, of East Pittsburgh, Pa., for his paper, "Effect of Skewing and Pole Spacing on Magnetic Noise in Electrical Machinery." (See A.S.M.E. Transactions, 1934, paper APM-56-15, pp. 711–720.)

Charles T. Main Award: George L. Williams, of Lafayette College, for his paper, "Coordinated Transportation—An Economic Comparison of Railroad, Bus, Truck, Water and Air Transportation for Long and Short Haul."

RETIREMENT OF E. S. NETHERCUT

It was voted to send felicitations and good wishes to Edgar S. Nethercut, upon his retirement as secretary of the Western Society of Engineers. (See MECHANICAL ENGINEERING, October, 1935, p. 672.)

REPRESENTATIVES AT N.C.S.B.E.E. CONVENTION

Paul Doty, James H. Herron, and C. E. Davies were appointed representatives of the Council at the annual meeting of the National Council of State Boards of Engineering Examiners, Columbus, Ohio, October 23–25, 1935.

WORLD POWER CONFERENCE

It was voted to accept the invitation of Assistant Secretary of State to be represented on the American National Committee of the Third World Power Conference and to appoint the president in office at the time of the conference as the Society representative.

APPOINTMENTS

Appointments were reported as follows: John Fritz Medal Board of Award, Ralph E. Flanders (four-year term); Subcommittee of Boiler Code Committee on Material Specifications, P. J. Smith (to succeed C. L. Warwick); Sectional Committee on the Standardization of Petroleum Products and Lubricants, George B. Karelitz and William F. Parish, alternates, Henry J. Masson, and Sydney J. Needs; Lehigh University, Inauguration of President Williams, Oct. 2, 1935, R. L. Sackett and W. H. Carrier.

Engineers Discuss Professional Recognition

UNITY in the approach to the problem of establishing adequate means for recognizing the engineer as a professional man is emphasized in the 1935 annual report of the Committee on Professional Recognition of the Engineers' Council for Professional Development, soon to be available in printed form, which attempts to clarify its position on the three avenues toward recognition that now exist—the legal sanction by professional registration, the professional degree of the engineering school, and admission to membership in one of the major engineering societies. Conrad N. Lauer, past-president, The American Society of Mechanical Engineers, is chairman of the Committee on Professional Recognition.

The report, which was adopted by the Engineers' Council for Professional Development, is part of its 1935 annual report. The Council is a conference of engineering bodies organized to enhance the professional status of the engineer through the cooperative support of those national organizations directly representing the professional, technical, educational, and legislative phases of an engineer's life. The participating bodies comprising the Engineers' Council for Professional Development are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society for the Promotion of Engineering Education, American Institute of Chemical Engineers, and National Council of State Boards of Engineering Examiners.

The report of the Committee on Professional Recognition takes pains to repeat the statement contained in its 1934 report that the Engineers' Council for Professional Development is not setting itself up as a central examining body whose findings are binding on all bodies, but that it is rather a convenience whereby lack of uniformity in methods of professional recognition may be coordinated and standards raised.

Three avenues toward recognition now exist. The engineering schools provide limited recognition through varied processes of granting the professional degree. A second avenue is admission to the corporate membership of the large engineering societies. The only avenue for recognition having legal sanction is through professional registration. E.C.P.D. constitutes a deliberative and advisory body, the effort of which is to be influential in harmonizing the standards of these several agencies and in bringing about a generally accepted concept of what may be termed the recognition of an engineer.

The objective such as is emphasized by E.C.P.D., says the report, admittedly is not immediately attainable. Before it can be established certain basic elements should receive attention and be determined. These elements are: first, a program of post-collegiate training with emphasis upon the cultural and social aspects of the engineer's life as well as his training and experience in pure technique;

second, the development of a standard by which to measure this post-collegiate attainment which will be adopted without further material question by the universities, by the boards of engineering examiners throughout the United States, and by the engineering societies.

The report emphasizes the fact that the registration of engineers is an important agency of recognition because it legally sets the standard for admission to the practice of the profession. Registration is operative in some form in 35 states and thus not only is, but must be acknowledged as, an established agency through which the professional status of an engineer will be recognized by himself, by the profession, and by the public. Furthermore, the registration is, for the engineer himself, of practical value, since it provides protection from those who would practice without qualification. It also provides a prima-facie evidence of individual capacity. However, it is pointed out that registration of engineers, as it exists in the various states, is not as yet sufficiently uniform to be fully satisfactory, as an analysis of the provisions of those state registration laws appended to the report clearly indicates.

The registration of engineers, the report says, is an important element in this unified approach toward the establishment of adequate means for recognizing the engineer as a professional man. E.C.P.D. should, therefore, the report continues, address itself to rendering all possible assistance to effect uniform registration laws in states which now do not have them, to improving the registration laws where they now exist, and to effecting among those present laws a higher degree of uniformity as to requirements and as to form of recognition.

However, the report states, this is just a part of the work and, like other features, such as the granting of professional degrees and admission to corporate membership in the engineering societies, is a matter which cannot be achieved all at once. The committee recognizes that a minimum standard for the granting of professional degrees is desirable but the granting of degrees is a charter responsibility of the colleges, and the granting of corporate membership in engineering societies is a matter of concern to their respective governing bodies, as related to the principles which hitherto they have felt to be of great value.

The report also points out that estimates will vary as to when either of these two procedures may be more universally recognized and accepted as harmonizing with the attainment of professional status, and much remains to be studied and evaluated before full attainment can be expected. While this is similarly true, it is said, of the time required to perfect the registration laws, there appears to be in them, however, a more immediate prospect of a unified approach and a uniform result. All assistance which E.C.P.D. can render, therefore, toward the engineering registration movement should be constantly and persistently applied.

In view of the fact that some important misunderstandings have arisen in connection with the Program of Certification adopted by E.C.P.D. in October, 1934, and for other reasons, the Committee on Professional Recognition recommended that the Program of Certification be referred back to it for further study and clarification.

The report was accompanied by an appendix prepared by Dean Parker H. Daggett, of Rutgers College, analyzing the engineer registration laws of 35 states, which will be found on pages 783–788 of this issue of MECHANICAL ENGINEERING.

St. Louis Aeronautic Meeting

ON October 10, 11, and 12 the Aeronautic Division of The American Society of Mechanical Engineers held its ninth annual meeting in St. Louis. The three-day program was featured by technical papers of many prominent figures in American aviation. The Hon. E. L. Vidal, Director of Air Commerce, Department of Commerce, Washington, D. C., delivered the opening address, after a welcoming talk by Hon. B. F. Dickmann, Mayor of St. Louis. Flying exhibits, a banquet, and stag smoker rounded out the more technical end of the program represented by the papers.

A feature of the meeting was the triennial award of the "Spirit of St. Louis" gold medal to the late Will Rogers. This represents the third time the medal has been awarded, the first presentation having been made in 1929 to the late Daniel Guggenheim. The medal is given every three years in recognition of outstanding, unself-interested contributions to aviation. Will Roger's earnest and successful efforts to popularize aviation in his talks and writings was believed to be particularly meritorious. The presentation was made at the Friday evening banquet to Maj. J. H. Doolittle who received the medal for Mrs. Rogers. Harry Guggenheim, son of the medal's first recipient, made the principal address.

The technical program prepared by Major Doolittle, chairman of the A.S.M.E. Aeronautic Division, was of wide interest. Some of the leading papers included a discussion by P. E. Hempke, Department of Mechanical Engineering, Case School of Applied Science, Cleveland, on "Radical Developments in Aviation." W. E. Savage, of the U. S. Army Air Corps, Wright Field, Dayton, discussed "Wing and Tail Flutter, Causes, Effects, and Remedies." The "Small Privately Owned Airplane and Its Probable Future" was admirably presented by John H. Glesse, Chief of Aeronautical Developments, Department of Air Commerce, Washington, D. C.

Other interesting papers covered the "Physiological Effects of Flight on Pilot and Passengers," by Wade Hampton Miller, a similar viewpoint being treated by Maj. David A. Myers, who asked, "Can the Human Body Keep Pace With the Airplane?" At a heavily attended evening meeting H. J. E. Reid, engineer in charge of Langley Aeronautical Memorial Laboratory, explained "Unique Methods and Equipment Used in Aeronautical Research by the National Advisory Committee for Aeronautics." Air transport problems were discussed by Harold Crary, vice-president in charge of traffic for United Airlines Transport Co., and Paul A. Gareau, chief dispatcher, American Airlines, Inc. Newark Airport. Lieut. B. B. Talley of Wright Field had an interesting and instructive exhibit on "Aerial Photography."

The meeting was directed by Major Doolittle and his national committee. Local arrangements were arranged and directed by a committee of the St. Louis Section headed by Victor J. Azbe.

Exposition of Chemical Industries, New York, Dec. 2–7, 1935

THE Fifteenth Exposition of Chemical Industries will be held at the Grand Central Palace, New York, Dec. 2–7, 1935. Materials, products, and machines will be displayed. Semi-works and plant equipment for all of the unit process industries will be graphically demonstrated. Visitors will be able to see the chemicals themselves, study machines in operation, and, in some cases, witness the production and packaging of the finished product.

The 1935 exposition will be divided into the following classifications: Chemicals and chemical products, plastics, molded products, lacquers, laboratory equipment and supplies, general equipment, instruments of precision, containers and packaging equipment, materials-handling equipment, raw materials, natural resources and industrial opportunities, and educational exhibits.

A.A.A.S. Meeting, St. Louis, December 30 to January 4, Section M Plans

PLANS for the winter meeting of the American Association for the Advancement of Science, to be held in St. Louis, Mo., during the week of Dec. 30, 1935, are being completed. Section M (Engineering) will meet at the Engineers' Club, on Friday evening, January 3. The program will include an address by Karl T. Compton, member, A.S.M.E., president of the Massachusetts Institute of Technology, which will deal with the work of the Engineers' Council for Professional Development in so far as this represents the awakened consciousness of engineers to their responsibilities in a civilization founded on applied science.

The Gibbs Memorial Lecture will be delivered on Thursday, January 2, at 4:30 p.m., in the Municipal Auditorium. Vannevar Bush, member A.S.M.E., Dean of Engineering, Massachusetts Institute of Technology, will deliver the address on the general subject of mechanical analysis.

The details of the program for Section M are being arranged by A. S. Langsdorf, member, A.S.M.E., dean of the Schools of Engineering and Architecture, Washington University, St. Louis, Mo., in cooperation with E. O. Sweetser, president, and C. W. S. Sammelman, secretary, of the Engineers' Club of St. Louis.

Funds for Unwin Memorial Solicited

"A GREAT teacher, a sound engineer, and a fine character." Such was William Cawthorne Unwin, honorary member, The American Society of Mechanical Engineers, who died on March 17, 1933, in his ninety-fifth year.

On February 13, 1935, at a meeting of Professor Unwin's friends and former students, it was decided to invite subscriptions to establish a fund to be utilized in commemorating the services he rendered to engineering by way of research and published writings and the leading part he took in the scientific training of engineers.

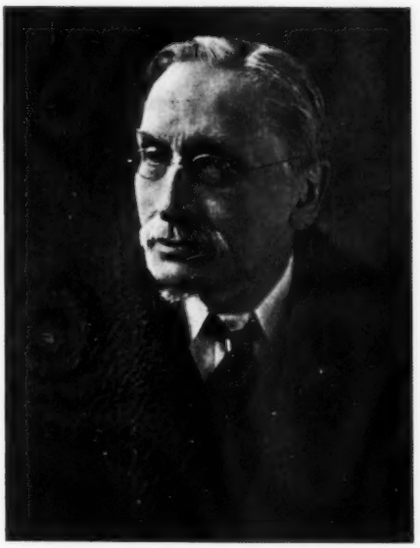
To this end, a committee has been formed of which Sir Alfred Chatterton is chairman, and on which are serving representatives of more than a dozen learned and engineering societies and educational institutions with which he was associated during his long life.

Representatives of The American Society of Mechanical Engineers on this committee, are James A. Hall, John A. Goff, and R. E. W. Harrison.

Professor Unwin's contributions to engineering that are of particular interest to engineers in the United States are his work in the initial hydroelectric developments at Niagara Falls and his numerous textbooks, used in our engineering schools.

In 1890, when the Cataract Construction Company began laying plans for the large-scale development of power at Niagara Falls, the problem of the engineering features involved was referred to an international commission consisting of Sir William Thomson (Lord Kelvin), president, Dr. Coleman Sellers, Prof. E. Mascart, of Paris, France, Col. Theodore Turrettini, of Geneva, Switzerland, and Prof. William Cawthorne Unwin, secretary.

The modern age to which the younger engineers now practicing belong finds it hard to understand the uncertainties that faced this commission. For the generation of electricity in large amounts by hydraulic turbines, the transmission of the current generated over long distances, its distribution and use in mechanical and chemical industries, and hundreds of technical problems such as the relative advantages of alternating and direct current were being attacked in pioneer fashion. Nor was it certain that the development should be an electrical one. Electricity was new; it had never been generated centrally in large quantities for distribution over long distances to points where it could be used. While lighting by electricity had been broadly introduced, industrial power was still largely by mechanical means. The Evershed project, upon which the Niagara scheme was based, was entirely hydraulic and contemplated a community of industries deriving their power from individual hydraulic turbines fed from a common canal—the use of power at the site. Mechanical (telodynamic) and pneumatic transmission systems were in a position to contend for consideration with hydraulic, steam, and gas methods of transmission and distribution. Moreover, the machinery and auxiliary apparatus, as well as the construction of the hydraulic details, were of a scale heretofore untried, so that the stakes, engineering as well as financial, were high and hazardous. Professor Unwin's book, "On the Development and Transmission of Power from Central Stations," comprising the Howard lectures delivered before the Society of Arts in 1893, contains his reflections on the methods in use and proposed at that time, and is indicative of the state of the art when the Niagara development was under consideration.



WILLIAM CAWTHORNE UNWIN

Professor Unwin, as secretary of the international commission conducting, on behalf of the Cataract Construction Company, the contest for the best solution of the Niagara problem, received the great variety of plans and proposals that were offered and, in 1893, wrote the report in which they were analyzed and appraised. It was this service that brought him into most intimate relationship with engineering on this continent and won for him, in 1898, honorary membership in The American Society of Mechanical Engineers.

Writing 25 years later of the work of the Commission, Professor Unwin said: "The projects were of extremely varied character. Hydraulic turbines of impulse and reaction types of from 2000 to 10,000 horsepower; distribution by electricity, by compressed air, and by wire ropes. Most of the electrical schemes proposed direct-current production and distribution with varying current and constant voltage. Messrs. Siemens proposed constant direct current at varying voltage; Professor Forbes only proposed alternating current. From the first, electrical distribution of the power was in favor, but was not definitely decided upon until May, 1893." Of the significance of the project itself he wrote: "Civilization may be measured by the degree in which human labor is replaced by power derived from natural sources of energy. . . . At Niagara some 7,000,000 horsepower which might have been available for industrial purposes was being wasted. The conditions were favorable for utilization in other respects for the fall was a high one and the Great Lakes from which the water flows act as reservoirs equalizing the supply. The installation has been carried out with complete success, and it is the first large-scale undertaking of the kind. It has been the parent of many others in different parts of the world, or at any rate showed the way to others to achieve a similar success. But the risk of misadventure in so novel and complicated an enterprise in the days when it was carried out was great, and that no serious mistake of judgment or calculation occurred witnesses to the remarkable care with which the preliminary investigations and discussions were conducted."

The Niagara decisions were momentous ones and have had their effect on the industrial and engineering development not only of the district immediately surrounding Niagara Falls and the city of Buffalo, but of the rest of the country and the world at large. For success at Niagara led the way to future developments, and gave a decisive answer to the major policies affecting the generation, transmission, and distribution of hydro power for years to come. It made feasible the development of sources of hydro power that are remotely located with respect to centers of population and ultimate use. It raised social, economic, and political problems in controversies over which this country in particular is still enmeshed. While many engineers and financiers were engaged in the historic events of those days, Professor Unwin played an important part that was in keeping with his character, training, and methods of work. For Professor Unwin was primarily a teacher and an investigator who analyzed and rationalized engineering science and practice and put the results of his studies and experiences in such a form as to make them available for all men, in all lands, and for all time.

Professor Unwin's career as a teacher began in 1868 with an appointment as professor at the Royal School of Naval Architecture and Marine Engineering at South Kensington. Four years later he was made professor of hydraulic engineering at the Royal Indian Engineering College, Coopers Hill, and in 1884 became the first professor of engineering at the Central Technical College of the City and Guilds of London. In the fulfillment of this office he rendered notable services to the school and to engineering education, and continued with his researches on the steam engine and the mechanics of materials.

No student of engineering can have escaped the influence of Professor Unwin's work. If his most notable textbooks, "The Elements of Machine Design," "Wrought Iron Bridges and Roofs," and "Testing Materials of Construction," are today not actually studied, for indeed they have been replaced by more modern texts, no later books on any of these subjects, or upon hydraulics, can be found without reference to his work, or without a formula bearing his name. For it was his especial ability to study the underlying theory, the practice, and the experimental researches in connection with these subjects and to evolve fundamental formulas upon which engineers

and designers could place reliance. While no great engineering structure stands today called by his name because his genius brought it into being as concrete evidence of a man's ability to perform spectacular engineering feats, it would not be an exaggeration to say that his work influenced those who have erected such monuments and provided at least some of the tools wherewith the designer worked.

Testimonial to W. W. Nichols

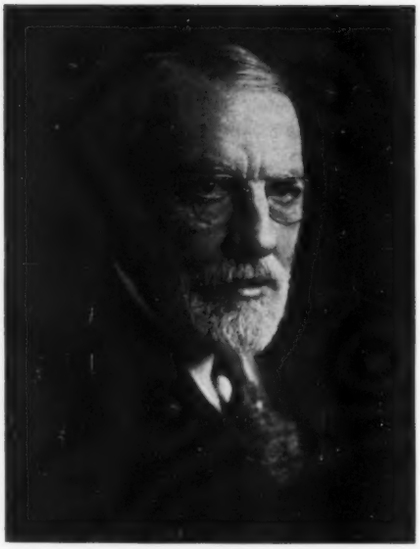
AT the first meeting this fall of the Detroit Section of The American Society of Mechanical Engineers held October 16 at the Fort Shelby Hotel, Detroit, Mich., a testimonial in the form of an illuminated address was presented by the Junior Group of the section to William Westervelt Nichols in recognition of the major part he took in founding the group and his kindly interest in furthering its activities during the past two years.

At the close of the dinner, in requesting Mr. Nichols to say a few words to the assembly, Sabin Crocker, chairman of the Detroit Section, dwelt briefly upon the forethought and industry of the speaker in laying the foundations of the Junior Group.

Mr. Nichols, who was greeted with a rising acclamation, spoke of his desire to aid the Society and further the professional spirit of engineering through encouraging junior members to organize an active group for themselves in preparation for taking part later in local section and national affairs. He urged the older members to give a helping hand, just as had been given to them in their youth, to the juniors who were in due course likewise destined to take over the conduct of the Society. He was glad to encourage the young engineers and would continue doing so as long as he was able.

Chairman Crocker then called upon A. M. Selvey to reply on behalf of the Junior Group of the Detroit Section. Mr. Selvey traced the development of the group, mentioning the large increase in junior attendance since activities were started. He showed how Mr. Nichols was endeavoring to pass on an example set to him many years ago in Philadelphia by John Edson Sweet, Founder Member, and how he, in urging Juniors to increase their personal contacts, had set an example by his membership in four American and five European national societies, being an honorary of the Masaryk Academy of Work of Czechoslovakia, by which country he had also been decorated with the Order of the White Lion for his placing in American industry many international-exchange work students.

Because members of the Junior Group of the Detroit Section honored Mr. Nichols for his good example and kindly interest, they presented to him an illuminated address. Mr. Nichols, with deep feeling, thanked the Group. Letters from President Flanders and several European engineers, and a testimonial-in-portfolio from Prague were read by Mr. Selvey and handed to the honored guest who graciously returned thanks. Thirty juniors and numerous members of the Detroit Section



W. W. NICHOLS

in attendance at the dinner congratulated Mr. Nichols on his good work and then adjourned to the technical session which followed.

Engineers Invited to Lehigh Valley Meeting, December 9

THE Engineers' Club of the Lehigh Valley, with which the Anthracite-Lehigh Valley Section of the A.S.M.E. is affiliated, and which has a membership of about 800 and covers an area including Monroe, Carbon, southern Luzerne, eastern Schuylkill, Lehigh, Northampton, and northern Bucks Counties and a portion of New Jersey immediately adjoining Northampton County, is planning to mark its Fifteenth Anniversary by a meeting on "The Industries of the Lehigh Valley," to be held in Packard Laboratory at Lehigh University on Monday, December 9, 1935. This meeting will consist of three parts:

(1) An Exhibit which will open at 2:00 o'clock in the afternoon. This exhibit will be put on by the leading industries of the Lehigh Valley for the purpose of showing the types and diversification of products manufactured in the Lehigh Valley. More than 50 industries have already signified their intention of exhibiting, and among them some of the largest industries in the country. This exhibit will be open to the public and will remain open all afternoon and evening. There will be no admission charged.

(2) A series of motion pictures covering the industries of the Lehigh Valley will be shown by the industries during the afternoon from 3 to 7 o'clock. The showing of these movies will be open to the public. There will be no admission charged.

(3) A paper is being prepared entitled "The Industries of the Lehigh Valley" (largely compiled by industry itself) and this paper will be read by an outstanding industrialist of the Lehigh Valley. This part of the meeting will be held in the Auditorium of Packard Laboratory at 8 p.m. and will last until some time past 10 p.m. Admission to this part of the meeting will be by ticket only, with preference being given to the members of the Engineers' Club and its affiliated societies and their guests.

Arrangements will be made for the serving of an evening meal, at a nominal price, to those visitors who come to the afternoon session and wish to remain through for the evening session. All engineers are invited to be present.

A.C.S. Symposium on Heat Transfer to Be Held at Yale, December 30 and 31

A SYMPOSIUM on heat transmission will be held at the Sterling Chemistry Laboratory, Yale University, New Haven, Conn., Dec. 30 and 31, 1935, under the auspices of the Division of Industrial and Engineering Chemistry of the American Chemical Society.

The committee in charge of the meeting has selected the subject of heat transmission because of its wide appeal not only to all chemical engineers but also to many industrial chemists and engineers in other fields. In arranging the program the committee has attempted to attract all those whose interests lie in the broad field of heat transfer, including heat conduction in solids, heat transfer by convection between fluids and solids, and heat transfer by radiation.

On the tentative program are papers by Albert B. Newman, Cooper Union; W. J. Wohlenberg, member, A.S.M.E., Yale University; W. L. Badger and Nathan Fragen, University of Michigan; E. F. Holser, The Dow Chemical Co.; Laurence Washington, junior, A.S.M.E., Stanford University, and Max Marks, Standard Oil Co. of Calif.; R. H. Heilman, member, A.S.M.E., Mellon Institute of Industrial Research; F. W. Adams, Massachusetts Institute of Technology; F. H. Rhodes, Cornell University; R. A. Bowman, junior, A.S.M.E., Westinghouse Elec. & Mfg. Co.; W. H. McAdams, member, A.S.M.E., Massachusetts Institute of Technology; E. N. Sieder, Foster Wheeler Corp.; G. H. Montillon, University of Minnesota; and A. D. Moore, University of Michigan.

Munich Hydraulic Reports Published in English

A TRANSLATION of Bulletin 3 of the Transactions of the Hydraulic Institute of the Munich Technical University has recently been published by The American Society of Mechanical Engineers. The original work, edited by Dr. Thoma, director of the Institute, has been rendered into English by a group of American hydraulic engineers under the direction of the Committee on Translations of the A.S.M.E. Hydraulic Division. Nearly all of the translators who collaborated in the task have participated in hydraulic researches in Germany as holders of scholarships provided by John R. Freeman, at whose suggestion the

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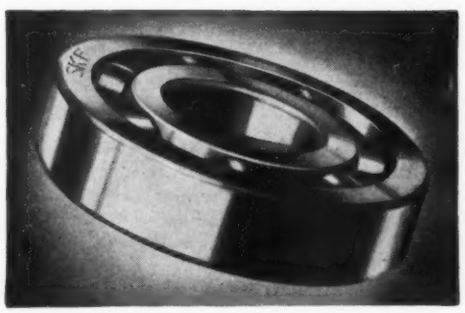

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Hydraulic Division formed the committee to direct the publication of such translations.

The book, a valuable companion to "Hydraulic Laboratory Practice," which likewise was published under the sponsorship of Mr. Freeman in 1929, contains translations of reports by leading German hydraulic engineers on such subjects as sources of error in weir measurements, losses in energy in several types of pipe bends, the Thoma counterflow brake, and a machine for testing the lubricating quality of oils. The book may be secured from the Publication Sales Department, The American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y., at three dollars a copy.

Memorial to Edison

OWEN D. YOUNG will serve as national chairman of the country-wide movement to honor Thomas Alva Edison by the establishment of a program to keep alive his ideals, William S. Barstow, president of The Thomas Alva Edison Foundation, has announced. National vice-chairman will be George B. Cortelyou.

The Edison Center for the Advancement of Youth in Science will comprise the physical setting from which a wide educational program will be developed with emphasis on the encouragement of youth in the pursuit of scientific knowledge, to be an ever-living memorial in keeping with Edison's life-long services to mankind, and particularly to youth.

The basic memorial will include facilities for the permanent care of Edison's personal library, which is probably one of the most valuable scientific libraries in existence, his records and papers, and originals or replicas of each of the more than one thousand inventions which he developed. The plans also include provision for a final resting place for the great inventor. Menlo Park, the scene of Edison's early activities, will be marked by a simple and impressive shaft, as a part of the general memorial program.

Officers of The Thomas Alva Edison Foundation are: William S. Barstow, president; William H. Meadowcraft, honorary vice-president; Lester W. W. Morrow and Frederick A. Scheffler, vice-presidents; and Walter S. Mallory, secretary and treasurer. These, with A. E. Kennelley, Howel H. Barnes, Jr., William J. Orchard, Charles F. Scott, Clayton H. Sharp, William H. Taylor, Preston B. Millar, and Arthur Walsh comprise the Board of Directors.

Industrial Lubrication Council

THE Industrial Lubrication Council, of New York, N. Y., of which William F. Parish is president, is planning to issue a lubrication manual and to conduct a correspondence course for the training of engineers in lubrication. The manual was developed at the suggestion of the A.S.M.E. Lubrication Engineering Committee, which felt that there was a need for training engineers in industry in the fundamentals of the application of lubricants.

A.E.C. News From Washington

THE Annual Assembly of the American Engineering Council will be held in Washington on January 9, 10, and 11. Preliminary to this meeting, a conference of the Council's Public Affairs Committee was held in Washington November 1. This Committee, made up of the chairmen of major subcommittees of the Public Affairs Committee, together with representatives of national and local societies, discussed several major public policies in which engineers have an opportunity for the expression of opinion.

The following subjects were included: Administration of public works; development of aeronautics; competition of Government with engineers in private practice; development of water resources; the trend in patent legislation; and the demand for rural electrification. Extensive discussion was given to various phases of these topics and approval was given to the development of complete reports on these subjects at the January meeting.

In line with the Council's many actions on the basic Federal survey and mapping program for the United States, it was voted that the Council continue to work for a coordination of basic mapping activities and that such a mapping program should not be considered an emergency or relief measure, but a fundamental matter underlying any program of national planning.

Further discussion developed around the relation of engineers to national planning. It was generally agreed that many of the Council's activities were themselves examples of the basic need, in the public interest, for a broader concept of national planning; that engineers, by their training and experience, can make contributions to social and economic, as well as technical, features of planning in its national as well as its state and local phases. The Public Affairs Committee, as a committee of the whole, considered recommendations as to how this movement may best be forwarded for presentation at the annual meeting.

The Public Affairs Committee recorded itself as in complete sympathy with the efforts of the National Civil Service Reform League to establish a wider public understanding of the essential value of the merit system. It was recommended that the staff of the Council cooperate with local and national engineering bodies to support the development and protection of the merit system as the only sound basis for improvement in the technical services of the Government.

It was proposed to take steps to coordinate further the work of the National Public Affairs Committee with the state and local public affairs committees in order that the Council, in all matters, be truly representative as a complete cross section of the profession.

A. A. POTTER NOMINATED FOR PRESIDENCY

At the meeting of the Executive Committee of the American Engineering Council, held November 2 in Washington, the Nominating Committee consisting of A. W. Berresford, Chairman, H. P. Eddy of Boston, and Robert W. Yarnall of Philadelphia, unanimously reported the selection of Dean Andrey A. Potter, past-president, A.S.M.E., as nominee for the presidency of the American Engineering Council for 1936–1937. Dr. Potter is Dean of the Schools of Engineering, Purdue University.

MEMBERSHIP CONTINUES TO EXPAND

The Council's membership continues to expand. When the new membership plan of nominal dues to state and local societies was adopted last January, sixteen such societies were members. Now the number is more than double and active steps toward joining are being taken by several others.

A.S.M.E. Amendments Pass

BALLOTS on the proposed amendments to the Constitution of The American Society of Mechanical Engineers relating to membership grades were counted by a special committee of tellers on November 12. All of the amendments, which will be found on page 532 of the August issue of MECHANICAL ENGINEERING, were voted on favorably.

Wm. F. Durand Awarded John Fritz Medal

WILLIAM FREDERICK DURAND, past-president, A.S.M.E., was awarded the John Fritz Gold Medal for 1936 for notable achievement "as authority in hydrodynamic and aerodynamic science, and in its practical application; outstanding leader in research and in engineering education." This award was made unanimously by the board, which has for its members sixteen past-presidents of the four American societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers. Presentation of the medal will be a feature of "Honors Night," Tuesday, December 3, at the Annual Meeting of The American Society of Mechanical Engineers, held in the Auditorium of the Engineering Societies Building, 29 West 39th Street, New York, N. Y.

Time-Series Charts

TIME Series Charts is a code of principles and practices in graphic presentation under preparation by a national committee on Standards for Graphic Presentation, sponsored by The American Society of Mechanical Engineers, under the procedure of the American Standards Association. The work on the code has advanced sufficiently to permit publication of a preliminary edition.

The code lays stress on the general principles of presentation and shows how these principles may be applied to meet the varying conditions surrounding chart preparation. The committee has kept in mind that standardization in graphic presentation can only be carried so far, and that flexibility of treatment is necessary.

Moreover, as effective chart construction depends not so much on a single broad decision as on a considerable number of minor decisions, recommendations in the code have been presented in considerable detail. While

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efficiencies of modern commercial single
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of this leaflet. The prospective purch
are sustained, or what it costs to sust
of maintenance costs, as herein quote
centrifugal pumps has now been so
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the code is developed around line charts for presenting time series, included also is a discussion of column and surface forms of time series charts, in so far as the principles and procedures applicable have not already been covered.

A limited number of copies of this edition of the code will be published early in 1936 to meet requests which have arisen and for the purpose of securing constructive criticism from those interested in the general improvement of the graphic method. Copies may be secured at $1 per copy from The American Society of Mechanical Engineers, Publication-Sales Department, 29 West 39th Street, New York, N. Y.

St. Louis Aeronautics Papers

AS announced in October (page 671) papers preprinted for the A.S.M.E. Aeronautic Meeting, held at St. Louis, Mo., October 10–12, were made available in a single volume obtainable from E. H. Sager, chairman of the St. Louis Section, Washington University, St. Louis, Mo. The price of the volume is $1.50. Copies of this volume may still be had.

Edward Epstean Honored

EDWARD EPSTEAN, member, A.S.M.E., and president, Photo-Engravers Board of Trade of New York, who represented the A.S.M.E. on the American National Committee for International Congresses of Photography at the ninth international congress, Paris, July, 1935, was awarded the Davanne Medal by the Société Francaise de Photographie in appreciation of his historical researches in photography and his English translation of French works relating to this field.

Coming Meetings of A.S.M.E. Local Sections

Chicago: December 11. Engineering Societies Building, 205 West Wacker Drive, Chicago, Ill., at 7:30 p.m. Subject: Management.

Cincinnati: December 5. Engineers' Club Auditorium. Subject: Design Elements of Modern Army Ordnance Equipment.

Colorado: December 27, 1935. Chamber of Commerce Dining Room, 6:30 p.m. Subject: Antifriction Bearings, by R. H. Fox, vice-president, Vulcan Iron Works Co.

Florida: December 27 and 28. Miami, Fla. Joint Meeting with the Florida Section, A.I.E.E.

Kansas City: December 5. Joint meeting with A.I.E.E. and A.S.M.E. with Student Branches of both Societies at Lawrence. Four papers will be presented by students, and a fifth paper from a member of the Kansas City Section Junior Group.

Louisville: December 6. Engineers' Clubroom, Norton Building, Louisville, Ky., at 8:00 p.m. A representative of Alexander Brothers, Inc., Chicago, Ill., will deliver the address.

Milwaukee: December 18. Wisconsin Club at 8:00 p.m. Subject: Golden Gate Bridge, by Clifford E. Paine, vice-president, Straus Engineering Co., Chicago, Ill.

Ontario. December 12. Room C-22 Mining Building, University of Toronto, at 8:00 p.m. Subject: Steam Locomotives, by W. Casey, manager, Canadian Locomotive Works.

Philadelphia: January 28. Engineers Club, 1317 Spruce St., Philadelphia, at 8:00 p.m. President-elect W. L. Batt will give a talk at 7:30 p.m. prior to the technical meeting. Subject: Non-Ferrous Metals, by Sam Tour, Lucius Pitkin, Inc., New York, N. Y.

Providence: December 10. Engineering Societies Building, Angell St., at 8:00 p.m. Joint Meeting with the A.I.E.E. Subject: Application of Motor Drives to Machine, by Mr. Harper, General Electric Company.

Syracuse: December 9. Onondaga Hotel, Roof Garden, at 8:15 p.m. Subject: Patents, by Theodore E. Simonton, patent lawyer, Dennison & Thompson, Syracuse, N. Y.

Schenectady: December 12. Subject: Water and the West, by Prof. Charles P. Berkey, Newbury Professor of Geology at Columbia University and Geological Consultant for the U. S. Bureau of Reclamation.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after December 26, 1935, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

New Applications

ACKER, SIDNEY H., Nashville, Tenn.
ANDRIOLA, ACHILLES D., Groton, Conn.
BROOKS, EDWARD DEF., Williston Park, L. I., N. Y.
BURGESS, NORMAN OSCAR, San Francisco, Calif.
COONEY, FRANCIS J., Brooklyn, N. Y.
DAY, JAMES A., Schenectady, N. Y.
EMERSON, JOHN PAUL, Demarest, N. J.
FINK, GEORGE E., Bellerose, L. I., N. Y. (Rt & T)
FRIEDLANDER, EDWARD A., Brooklyn, N. Y.
GEBHARDT, WILSON A., Cleveland, Ohio
GOSS, ROBERT J., New York, N. Y.
HUNTER, LOUIS N., Johnstown, Pa.
JENS, ARTHUR H., Chicago, Ill.
JUELSS, DAVE, Hoboken, N. J. (Rt & T)
KIMBALL, CLINTON, Cape Girardeau, Mo. (Rt)
LEE, FRANK H., New York, N. Y.
LONG, RICHARD H., Hollis, L. I., N. Y.
MACLEAN, DONALD, Waterbury, Conn.
MATUKAS, JOHN JOSEPH, Dedham, Mass.
MIDDLETON, LESLIE H., Toledo, Ohio
MULLOWNEY, P. E., Raleigh, N. C.
PEFF, IVAN, East Orange, N. J.
PRATT, HAZEN C., Rochester, N. Y. (Rt & T)
SCHROEDER, OTTO, San Francisco, Calif.
SMITH, ROBERT WARREN, Springfield, Ohio
WILLIAMS, F. NORTON, JR., Berwick, Pa.
WIST, EDWARD B., Alameda, Calif.
WYNNS, COLBERT B., Nashville, Tenn.

Change of Grading

Transfers from Associate

GOSSELIN, EDWARD N., Joliet, Ill.
MITCHELL, W. H., Niagara Falls, N. Y.

Transfers from Junior

DERR, THOS. S., Waban, Mass.
EAST, L. H., Rochester, N. Y.
HUGO, MERRILL S., Mountain View, Calif.

Necrology

THE following deaths of members have recently been reported to the Office of the Society:

ADSIT, CHARLES G . March 27, 1935
AHLQUIST, CARL R., June 3, 1925
DIETZ, PETER, September 13, 1935
EHRMANN, CHARLES, August 13, 1935
FELDMEIER, HARVEY, September 20, 1935
HALSEY, FREDERICK A., October 20, 1935
HART, FREDERICK, July 24, 1935
MORSE, FRANK L., March 25, 1935
POOL, JOHN F., August 29, 1935
RUBLE, JOSEPH S., September 4, 1935

A.S.M.E. Transactions for November, 1935

THE November, 1935, issue of the Transactions of the A.S.M.E., contains ten papers that are to be presented at the forthcoming Annual Meeting of The American Society of Mechanical Engineers, New York, N. Y., December 2-6, 1935. Persons desiring to offer discussion at the meeting are referred to these preprinted texts as a basis for their comment. The papers are as follows:

Cause and Prevention of Turbine-Blade Deposits (FSP-57-14), by F. G. Straub

Cavitation Testing of Model Hydraulic Turbines and Its Bearing on Design and Operation (HYD-57-13), by L. M. Davis

Radiation From Nonluminous Flames (PRO-57-4), by H. C. Hottel and V. C. Smith

Safe Operation of High-Speed Locomotives (RR-57-3), by B. S. Cain

Lateral Oscillations of Rail Vehicles (RR-57-4), by B. F. Langer and J. P. Shamberger

Measurement of Steam Rate and Indicated Horsepower of Locomotives (RR-57-5), by Arthur Williams

The Correlation of Spring-Wire Bending and Torsion Fatigue Tests (RP-57-1), by E. E. Weibel

Evaluation of Effective Radiant Heating Surface and Application of the Stefan-Boltzman Law to Heat Absorption in Boiler Furnaces (RP-57-2), by H. F. Mullikin

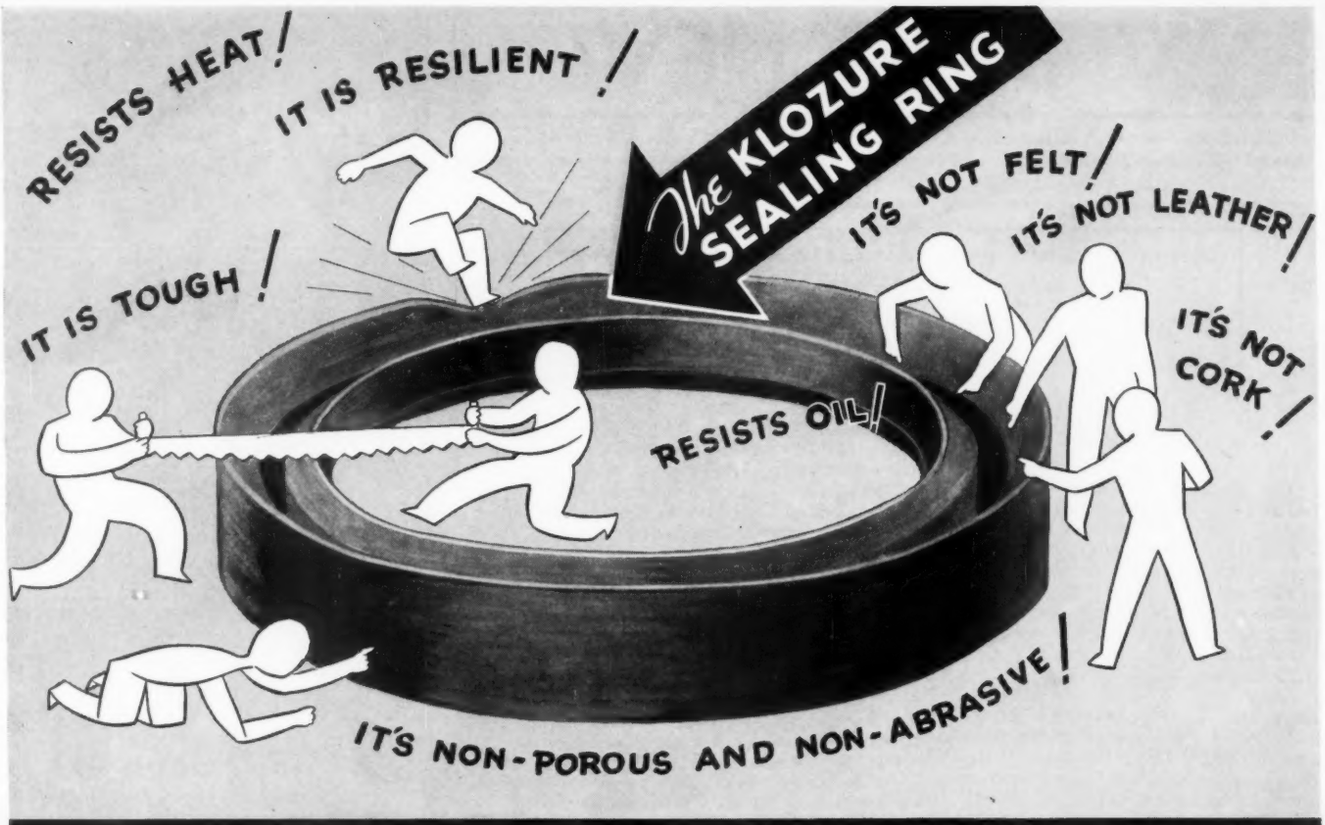
Review of Methods of Computing Heat Absorption in Boiler Furnaces (RP-57-3), by W. J. Wohlenberg and H. F. Mullikin

An Experimental Investigation of Heat Absorption in Boiler Furances (RP-57-4), by W. J. Wohlenberg, H. F. Mullikin, W. H. Armacost, and C. W. Gordon

Discussion

On previously published papers by L. Helander; and A. M. Norris.

For closing dates on discussion, see footnote on first page of each paper.



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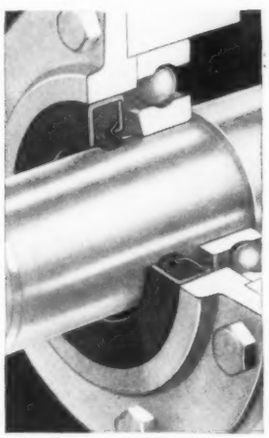

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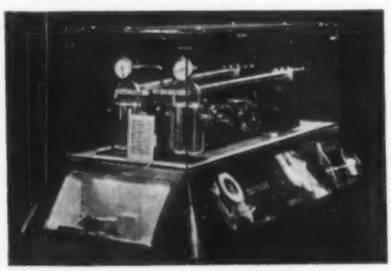
Electric Refrigeration and Air Conditioning Machinery Lubrication

The development of the machinery essential to a new industry or to any branch of an already established industry has always presented a variety of unique problems. Wherever operating mechanisms are involved, lubrication must always be given the most careful study. In the operation of electric refrigeration and air conditioning machinery, lubrication must be studied in conjunction with the possibility of chemical reactions between petroleum oils and the types of refrigerants so extensively used. This is a vital question for every manufacturer of air conditioning and electric refrigeration equipment.

In anticipation of the problems which may arise and to foster more intelligent study of the lubrication requirements of such equipment, The Texas Company has published two comprehensive articles in their magazine *Lubrication* for August and October, 1935. Copies of these articles may be obtained by communicating with The Texas Company, Technical Division, 135 East 42nd Street, New York, N. Y.

New Testing Machine

Illustrated below is the unique testing machine developed by the International Nickel Co., Inc., 67 Wall Street, New York, N. Y., and displayed in the booth of the Warner & Swasey Co. at the Machine Tool Show recently held in Cleveland. This device demonstrates one of the several outstanding characteristics of nickel cast irons which make them particularly useful for the construction of heavy duty machine tool parts, i.e., the greater stiffness (modulus of elasticity) of the alloyed cast iron.



Two cast iron bars of exactly the same finished dimensions (42″ long by 2¾″ wide by ¾″ thick) are tightly clamped to rigid supports at one end so as to allow a cantilever length, in each case, of 35½″. Identical weights of 50 pounds each are mounted, at the ends of the cantilever, with an automatic device to alternately support and release this load on a 60-second cycle; 20 seconds at rest, 10 seconds down as load is applied, 20 seconds rest with full load applied, 10 seconds up as load is supported by rocker arms. Strain gauges rigidly mounted at the top of the travel indicate in thousandths of an inch the relative strain of the two types of iron as the loads are applied, supported and released. Deflections with full load applied were 0.430″ in the case of the high test nickel cast iron and 0.654″ in the case of the ordinary cast iron. Both beams were highly finished and scraped to simulate the finish used on machine tool lathe beds.

The moving parts were entirely inclosed in glass as indicated. On the front and rear of the case which inclosed the base were translights illustrating various steps in the production of Warner & Swasey lathe beds. At one end were samples of the ingredients used in the production of 80% steel base, 1½% nickel cast iron, with fractures of the high test iron and the ordinary cast iron, showing the structure, and in each case, a small machined section showing the Brinell hardness values. At the other end were 3 dimension charts showing the relative mechanical properties (strength, hardness, deflection and modulus of elasticity) of the two types of iron.

Cast Iron Soil Pipe and Fittings

Is a new American Standard covering nomenclature, materials, marking and inspection, dimensions and weights. Specifications apply to soil pipe and fittings in sizes 2 in. to 6 in. and 8 in. to 15 in. Price 65 cents. Obtainable from the A.S.M.E. Publication-Sales Dept., 29 West 39th St., New York, N. Y.

Handbook of Industrial Tires

Of interest to practically every operating executive in all industries, a 24 page "Handbook of Industrial Tires" has just been published by The B. F. Goodrich Company, Akron, Ohio, and is now available upon request.

First pages are devoted to reviews of exhaustive tests which show that rubber tires leave floors unharmed, while steel wheels on industrial equipment cause constant maintenance costs; less power is required with rubber tires to start loads and keep them moving; rubber tires even out the bumps and thus save power consumption or human energy as well as speed up operations.

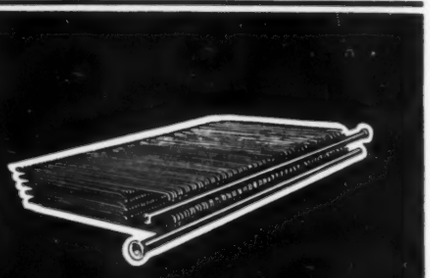
Other pages give hints on how to select the right tire for the particular type job; how to handle changeovers from steel wheels to rubber tired equipment, and discuss the four types of rubber compounds which meet the tire demands of industrial users in many and varied services.

Description of the new "Vulc-On" rubber tired industrial wheels, together with a size and specification table giving detailed data on the tire problem is also included, as are size and specification tables for many other types of industrial tires which the company manufactures.

Three pages are devoted to the Goodrich pneumatic wheelbarrow tire, the industrial pneumatic types and the Zero Pressure Pneumatic, which cannot go flat, and is applicable in a great many industrial operations, particularly in yard work.

Continued on Page 14

Improved



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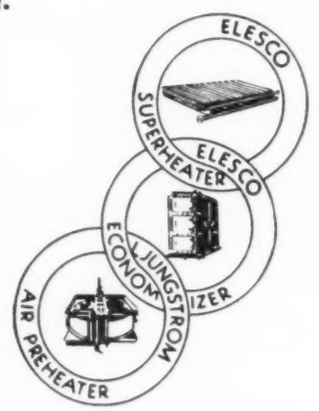

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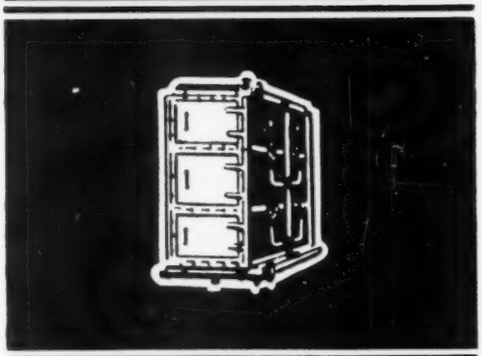

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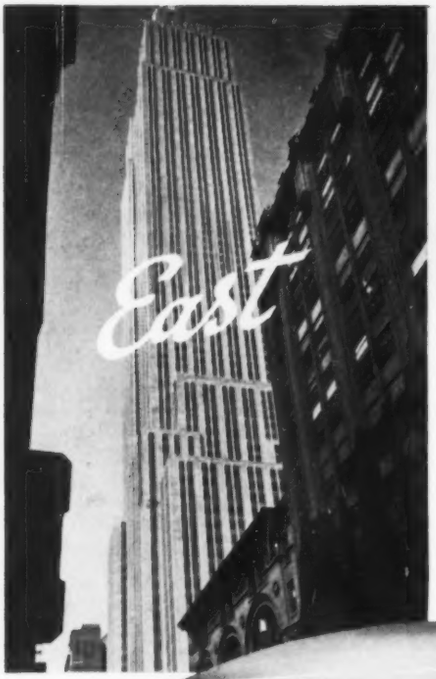

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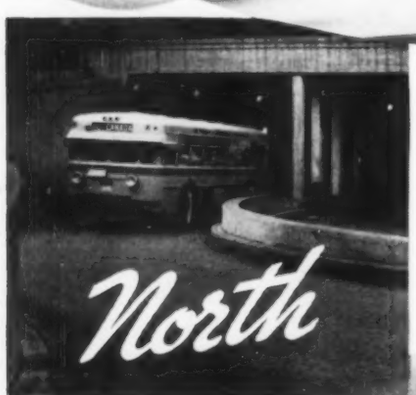

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for Air Conditioning, Ventilating, Heating, Mechanical Draft, Drying, Vacuum Cleaning, Pneumatic Conveying, Dust Collecting, Compressing, and other Related Purposes.

WHAT'S NEW EQUIPMENT MATERIALS · CATALOGS · BUSINESS CHANGES · ETC. *Continued from Page 12*

Mechanical Combustion Control

A new 32 page Data Book No. S-20 has been recently published on the subject of Mechanical Combustion Control. It contains a complete discussion of the basic problems of boiler operation and an evaluation of their importance in the final result—efficient steam generation.

This Data Book is fully illustrated and contains a large number of full page diagrams showing the application of Mechanical Control to various types of boiler and fuel firing equipment.

A copy can be obtained without obligation by writing to Smoot Engineering Corporation, 2232 Diversey Parkway, Chicago, Illinois.

A New, Completely Enclosed, Cartridge Type Precision Ball Bearing

The Norma-Hoffmann Bearings Corporation, Stamford, Conn., announces an addition to its extensive line of self-protected Precision Bearings, in the form of a completely enclosed cartridge type single-row unit designated as the "3000" Series.

The "3000" Series, although having but one row of balls, has inner and outer rings of standard double-row width. The bearing is completely enclosed, and protected on both sides, by metal seals of special design held firmly in place by snap-rings in the outer race. These metal seals have a long inwardly projecting flange with a close running fit over the grooved and recessed inner ring. The latter arrangement, while entirely free from rubbing friction and wear, forms an effective and permanent seal against the escape of lubricant. The metal sealing plates are easily removable for inspecting or cleaning the bearing. The bearing is handled as a complete, self-protected cartridge unit at all times.

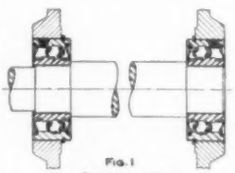

Fig. 1 Simplest method of opposed mounting using snap wires on bearings

The wide inner and outer rings give two great advantages. First, exceptionally large grease capacity is afforded, sufficient for long periods of continuous operation under average operating conditions. Second, looseness or "peening" of either shaft or housing is obviated by the greater contact area the wide rings provide. In most cases, lock nuts on the shaft are not required.

The "3000" Series Bearing can be furnished either with or without a filling plug for renewal of grease. Where the filling plug is not employed, regreasing is effected by removing and replacing one seal. The new bearing can also be furnished with, or without, the snap ring on the outer race.

In many cases it is possible to reduce the overall length of the unit in which the "3000" Series Bearing is employed, because of the elimination of sealing devices otherwise required. Supplementary protecting parts are usually obviated, also, and the assembly simplified accordingly.

The "3000" Precision Bearing is made chiefly in the medium series starting at 25 m/m bore. Patents are pending, covering all distinctive features. The illustration shows the bearing construction in cross-section, as well as the simplicity and compactness of a typical mounting.

This Grinder Housing
thrives on Hard Knocks

LIGHT WEIGHT, rugged strength, and low heat conductivity are properties which should be inherent in any material used for the housing of an electric shop tool. Light weight for easy handling, low heat conductivity for comfort, and strength to withstand "hard knocks". Because all three required properties are combined in Impact Bakelite Molded it is used for the housing of the Skilsaw Hand Grinder.

This versatile Bakelite Material not only provides the essential physical and thermal properties, but also high electrical insulation value and resistance to water, brine, chemicals, oils, acids, wear and abrasion.

The use of Impact Bakelite Molded also permits the complete forming of the 2-piece grinder housing in two operations of the molding press. Machining and finishing are eliminated because each part leaves the press accurately dimensioned, and with a smooth natural finish throughout. Economies in assembly are effected, because metal inserts are firmly and accurately embedded during the single molding process.

The Bakelite Material used for the Skilsaw Grinder is but one of many types. It is probable that one or more of these could be used to advantage in your own product. You may get a clear idea of the possibilities of Bakelite Materials by writing for descriptive booklet 32M, "Bakelite Molded" which shows a wide variety of present-day applications.

★

(Above) Skilsaw Hand Grinder made by Skilsaw, Inc., Chicago, Ill., and (left) the 2-piece housing of Impact Bakelite Molded.

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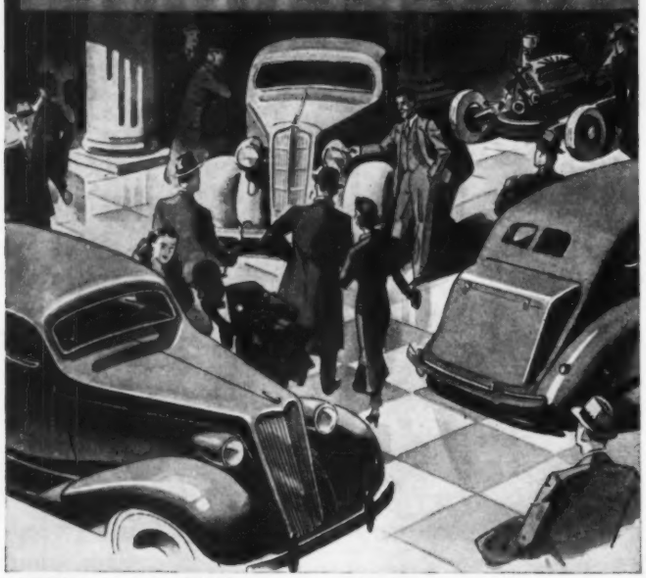

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U. S. Pat. 1,419,564—1,604,122—1,697,954—1,782,387
Other Pat. Pending—Foreign Pat.

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A Hele-Shaw pump develops the high hydrostatic pressures used in a Hydraulic Pipe Testing Machine (Lassman System) operated by Spang-Chalfant & Co. at their Ambridge, Pa., seamless tube plant. Seven years of service, often for 24 hours continuously, have not cost a cent for repairs.

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Fluid Power, applied through Hele-Shaw pumps or transmissions, for producing variable reversible linear or rotary motion is seldom an "over-the-counter" proposition. Our Engineering Department, skilled on the application of Fluid Power to the diverse problems of industry, will gladly determine its possibilities for you.

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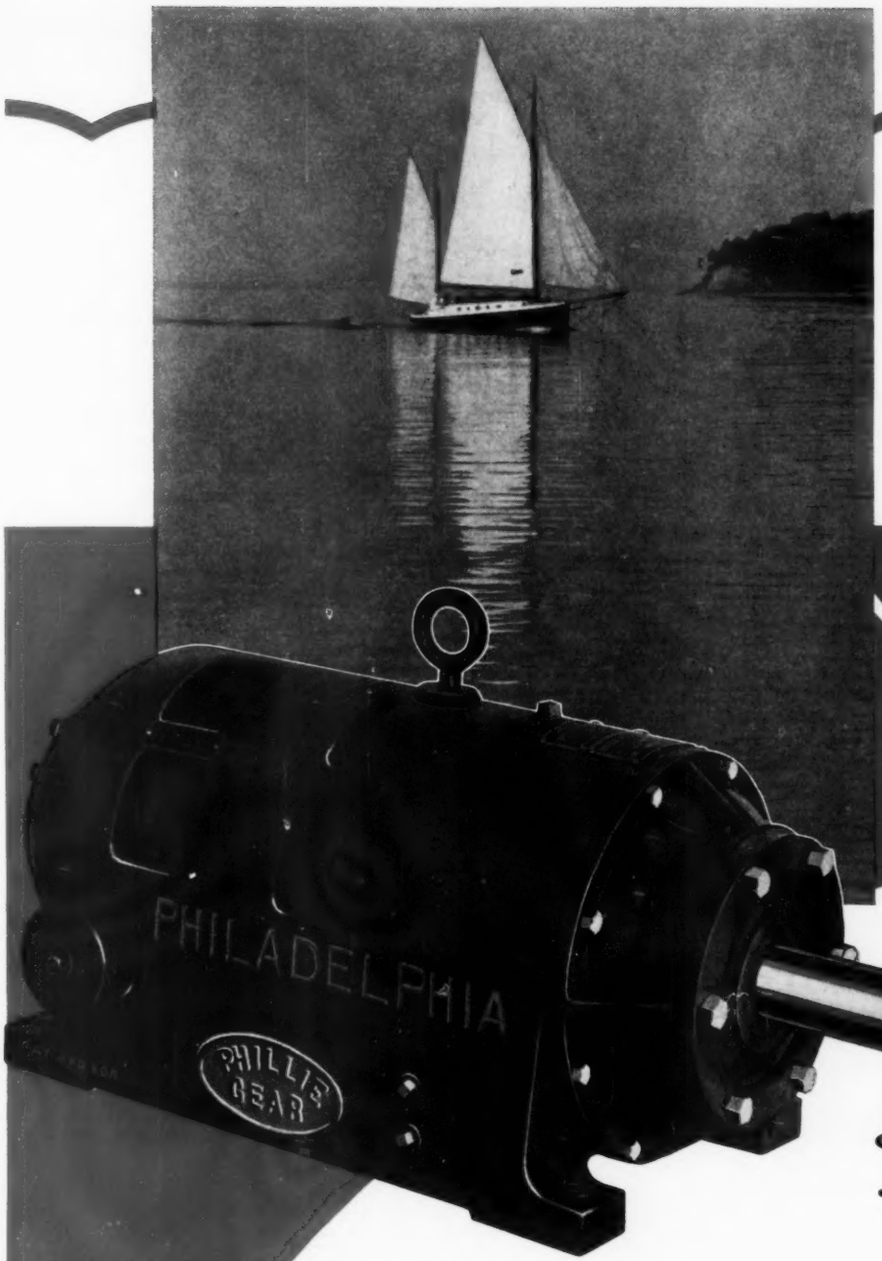

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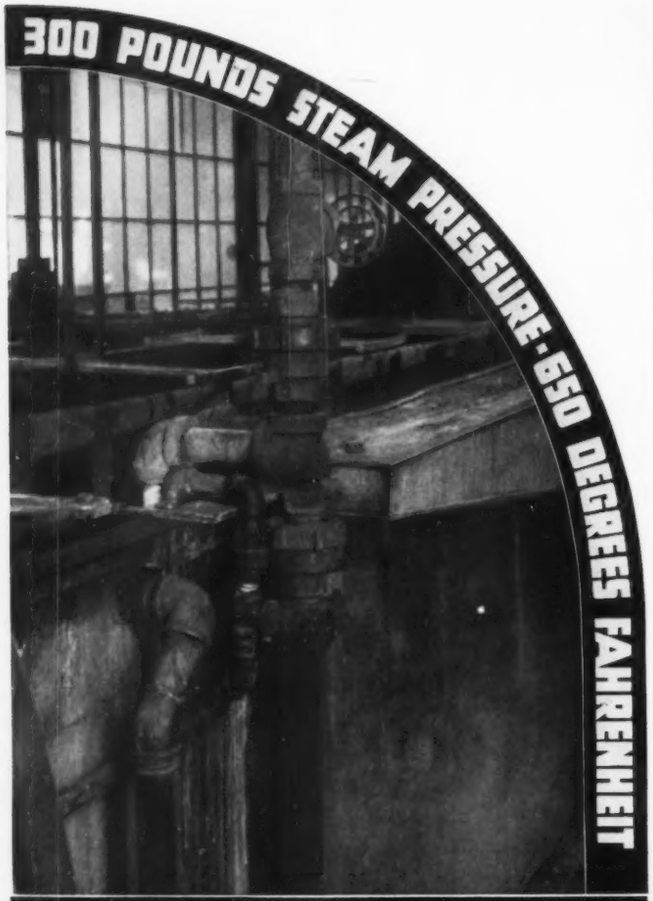

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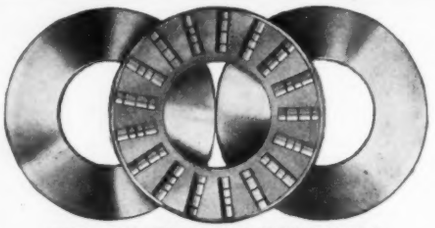

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. . . and see our page 43

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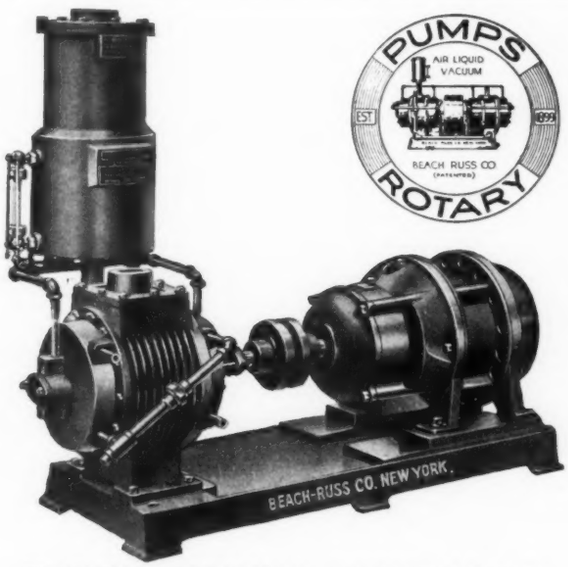

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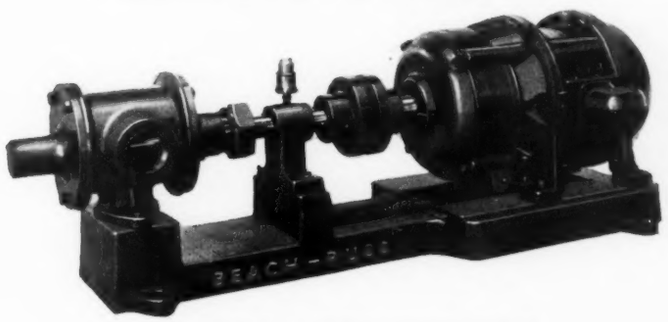

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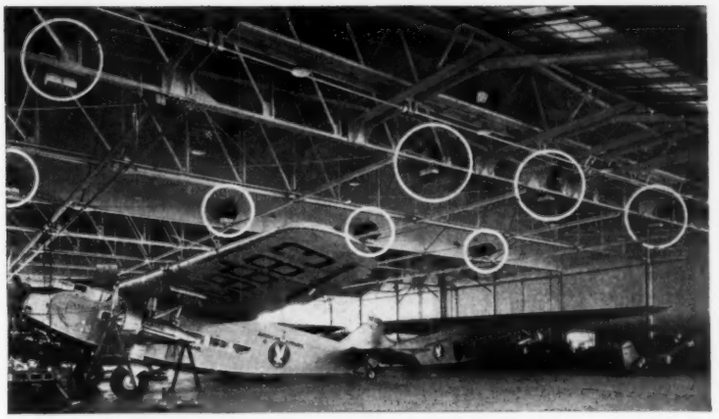

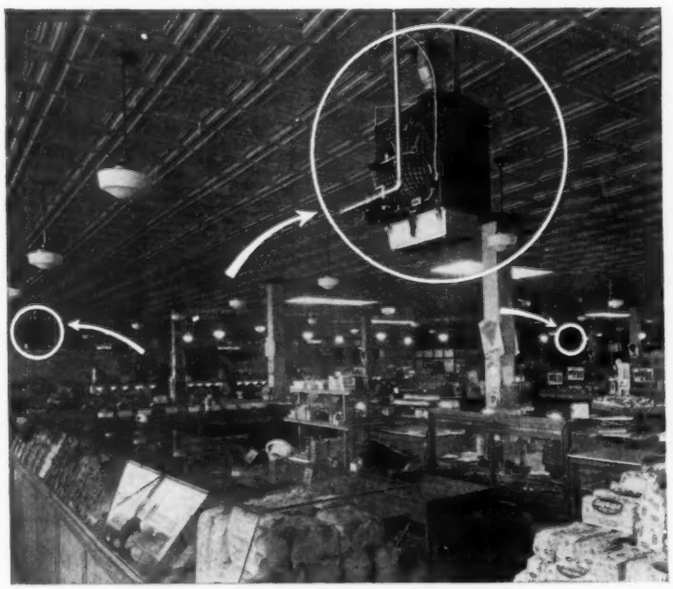

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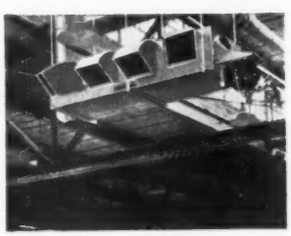

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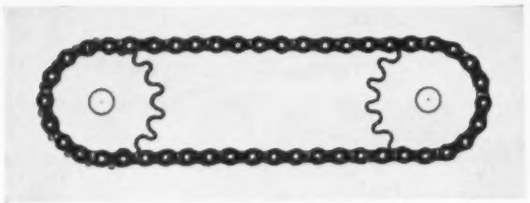

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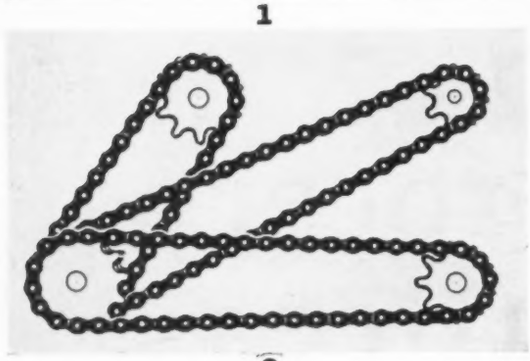

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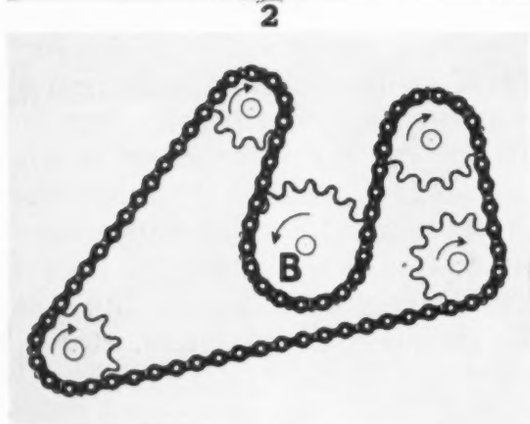

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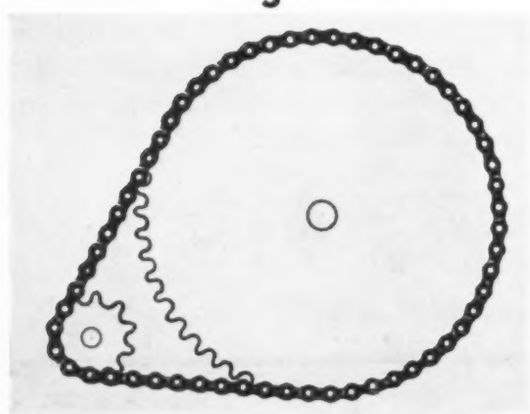

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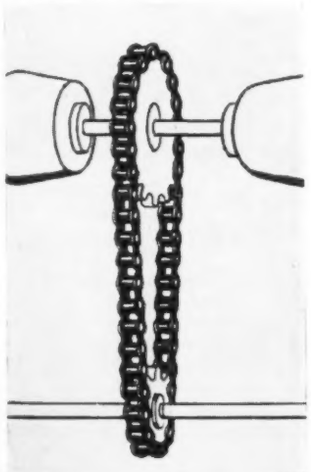

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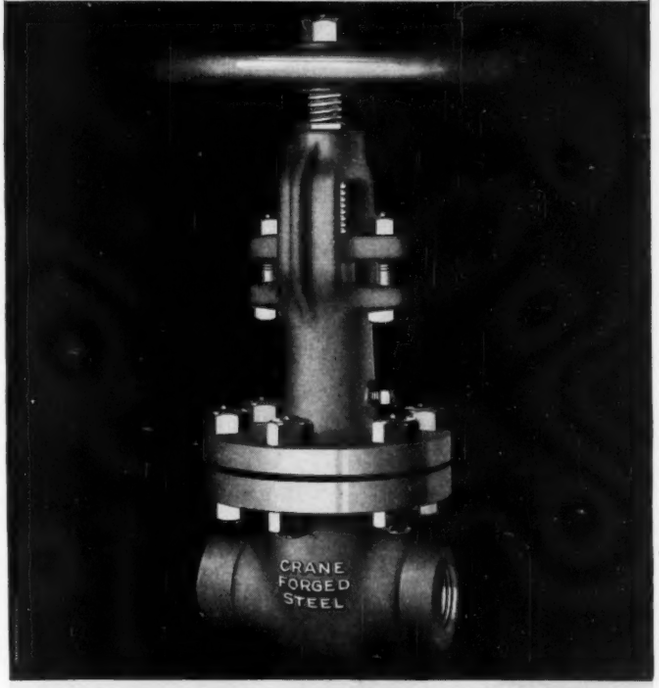

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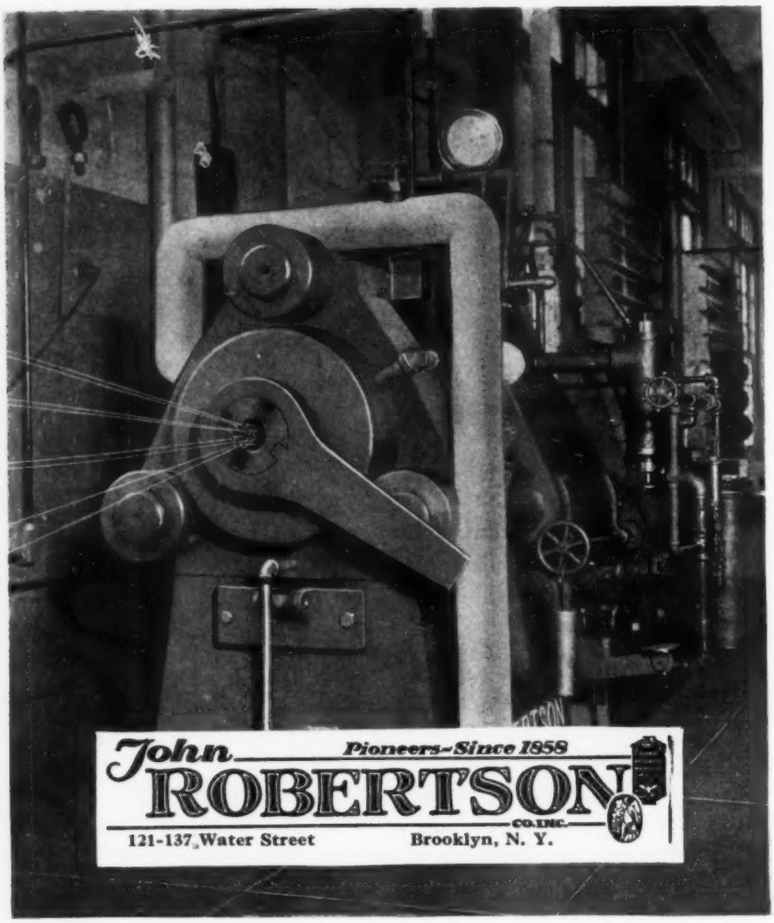

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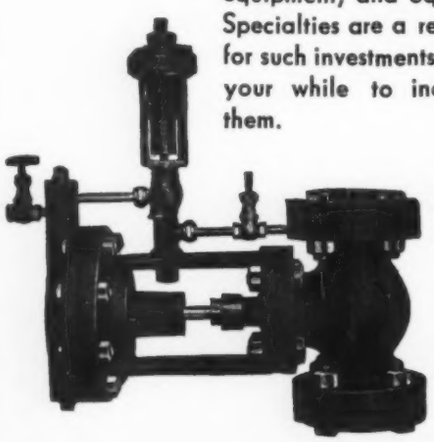

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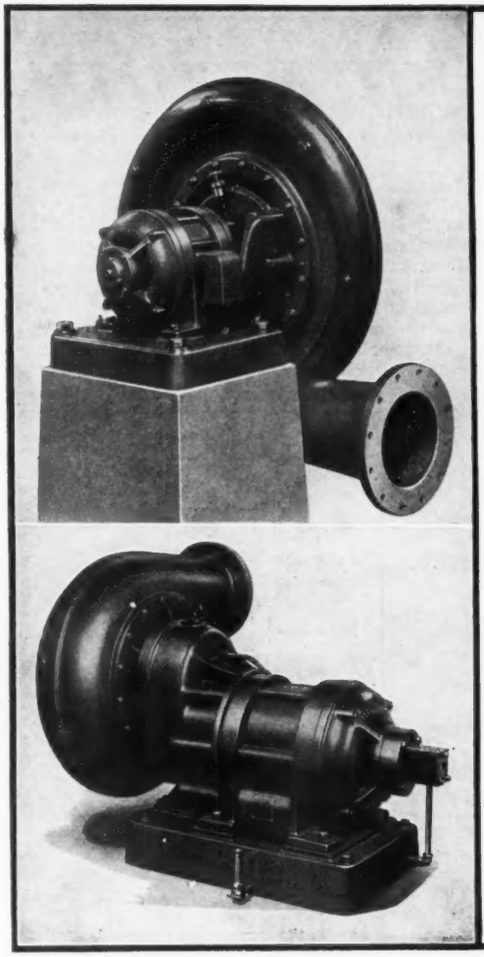
Pending its final approval, a limited edition of this code will be published early in 1936 to make the material available without further delay. It consists of 64—8½ × 11 inch pages, including more than 100 illustrations. Price $1.00. Obtainable from the A.S.M.E. Publication-Sales Department, 29 West 39th St., New York.



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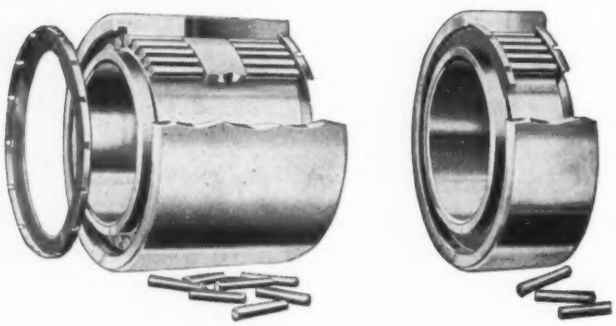

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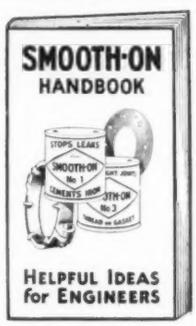

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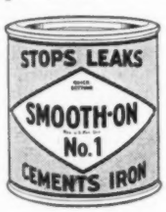

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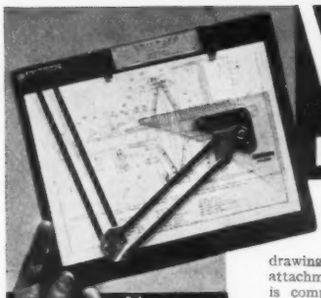

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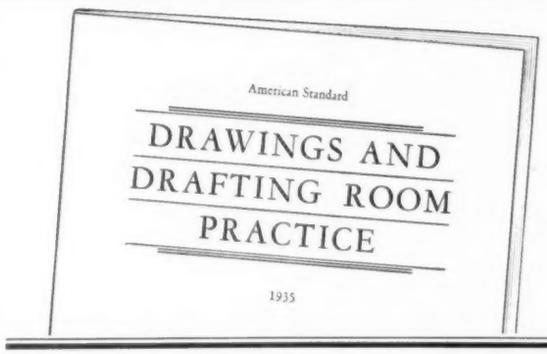

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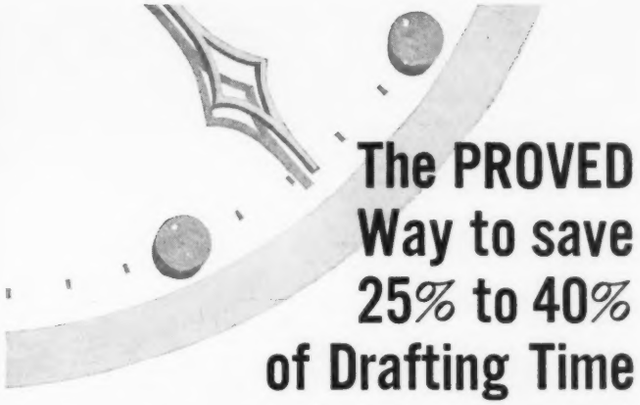

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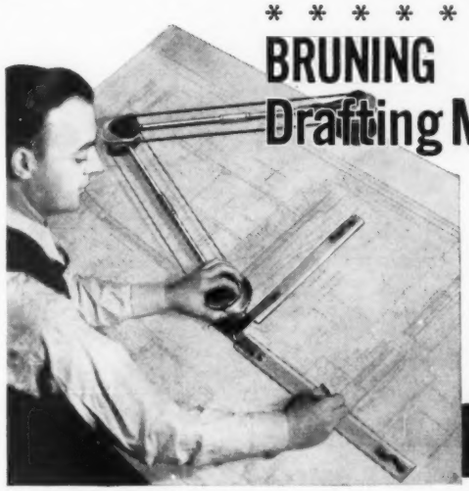

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THE GIFT OF FRIENDSHIP

THERE is a priceless gift within reach of every one—the gift of friendship.

Of all the services of the telephone there is none more important than this—helping you to make friends and to keep them.

When people are in trouble, you go to them quickly by telephone. The telephone carries your good wishes on birthdays, weddings and anniversaries. Arranges a golf game or gets a fourth for bridge. Invites a business acquaintance to your home for dinner, and advises "home" that he is coming. Congratulates a youngster on his work at school. Thanks a neighbor or asks about the baby. Renews old times—shares confidences—plans for the future.

Thus the bonds of friendship are formed and strengthened. Greater happiness comes into the widening circle of your life. Some one, somewhere, says sincerely—"It was nice of you to call." This day, a voice-visit by telephone may bring reassurance to some friend who is wondering how you are.

More and more are people turning to Long Distance to carry friendly voices across the miles. They like its speed, clarity, intimacy and low cost—especially after 7 P.M., when calls by number to most points cost about 40% less than in the daytime.

BELL TELEPHONE SYSTEM

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PRECISION ROLLER BEARINGS afford the following outstanding advantages . . . Solid, cylindrical rollers, held to infinitesimal limits of accuracy, provide larger steady load and shock capacity than any other single-row bearing, together with a temporary overhead capacity of 50% . . . Short roller construction affords ideal load distribution and greater wear resistance . . . Extruded bronze, machined and balanced, heavy-duty retainer is land-riding, relieving the rolling elements of its weight . . . Extreme refinement of design and finish gives a lower coefficient of friction under severe load than any other type of bearing and permits speeds up to 35,000 R.P.M. . . . PRECISION ROLLER BEARINGS interchange in size with all standard ball bearings . . . Write for the catalog. Let our engineers work with you.

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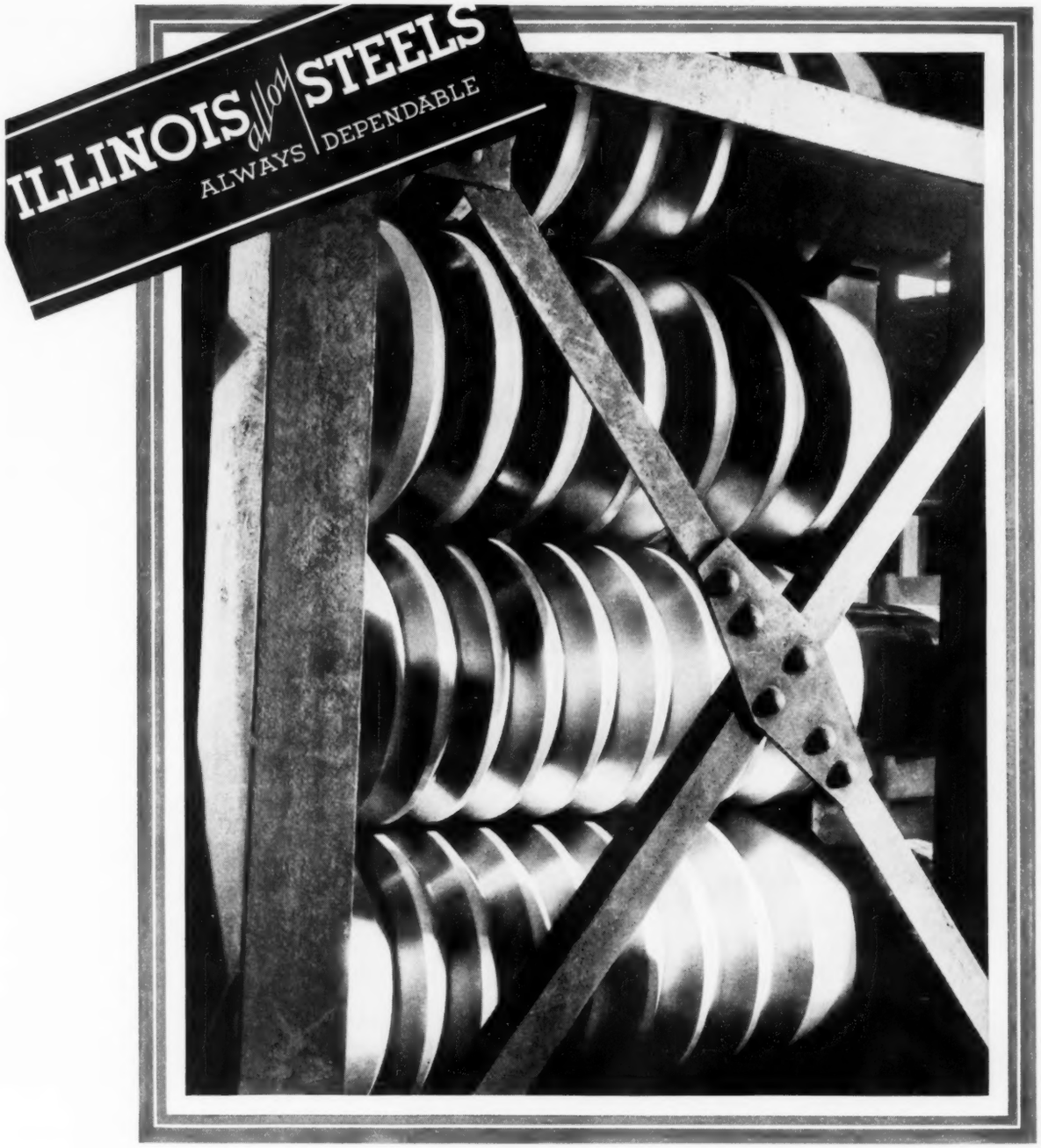

THE SQUARE IS IN THE ROLL

● Sharp, clean, square edges on alloy bar stock depend on the excellence of the rolls and the proper control of heat and speed in the rolling operations.

The rolls used by Illinois Steel Company in its alloy bar mills are made of the finest and most suitable material, carefully machined and hand-finished. And they're kept in shipshape condition. Whether you order rounds, squares, hexes or other shapes, you'll find your Illinois Alloy bars true to shape, straight as a die, finished to assure perfect surfaces and inspected piece by piece. For uniformity as well as for quality, specify Illinois Alloy Steel.

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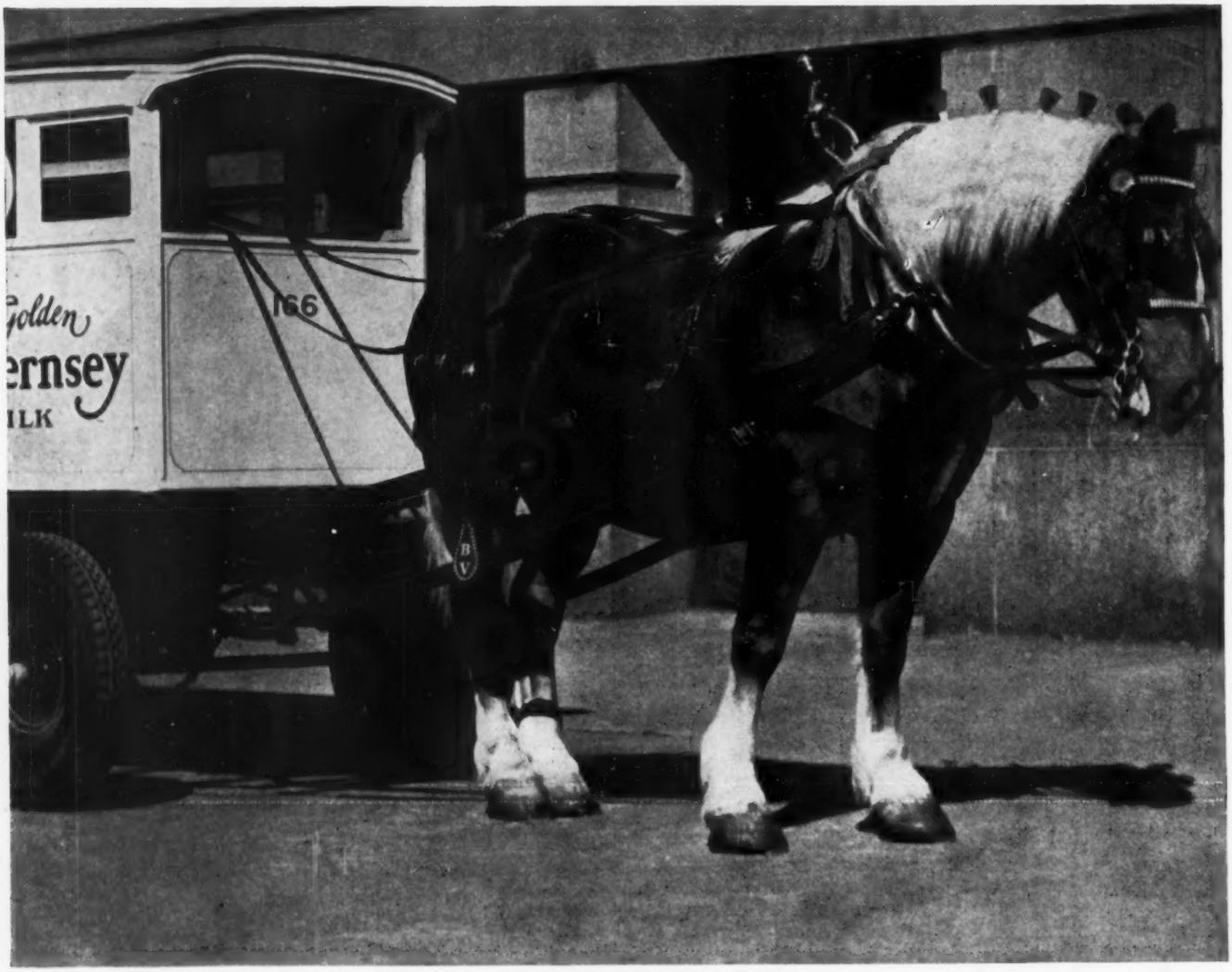
"MONEY MAKES THE MARE GO"



BUT RUBBER BRINGS HER BACK

THE horse is staging a comeback, and *rubber* is one of the chief factors making that comeback possible.

Along congested milk and bakery routes, it is found that time is saved because the horse starts and stops without attention or time from the driver. The horse even stops at the right houses of customers, if a new driver forgets some of the addresses!

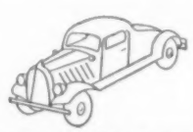
But to return to horses meant noisy clomping and clatter—until Goodrich perfected horseshoes and calks of rubber which make no noise, outwear old iron shoes, and save energy of horses as well as sleep and nerves of customers.

Rubber for silence has a thousand applications in industry today. Silence could improve the salability of many a product, or could reduce fatigue of workers and machinery and so reduce costs.

But silence is only one of a host of attributes of modern rubber as Goodrich compounds it. Goodrich rubber can be made in almost any color, texture or form; it can absorb vibration; it can flex countless times without ageing; it can resist chemicals, oil, heat, abrasion; it can be attached inseparably to almost any other material. Goodrich rubber is really a myriad of products. Some one of its many new qualities is almost certain to be valuable to you, no matter what your product or process.

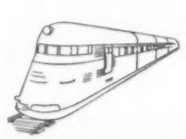
Why not let Goodrich application engineers explore the possibility with you? The B. F. Goodrich Co., Mechanical Rubber Goods Division, Akron, Ohio.

• An automobile maker reduced motor vibration by suspending the motor from the frame with Goodrich rubber dampeners mounted in shear.



• Toy automobile sales doubled when wheels were changed from noisy, destructive metal to silent, safe, life-like Goodrich rubber tires.

• A milk company has reduced its breakage bill by equipping its metal baskets with rubber strips. Also it ends early-morning rattle of glass.



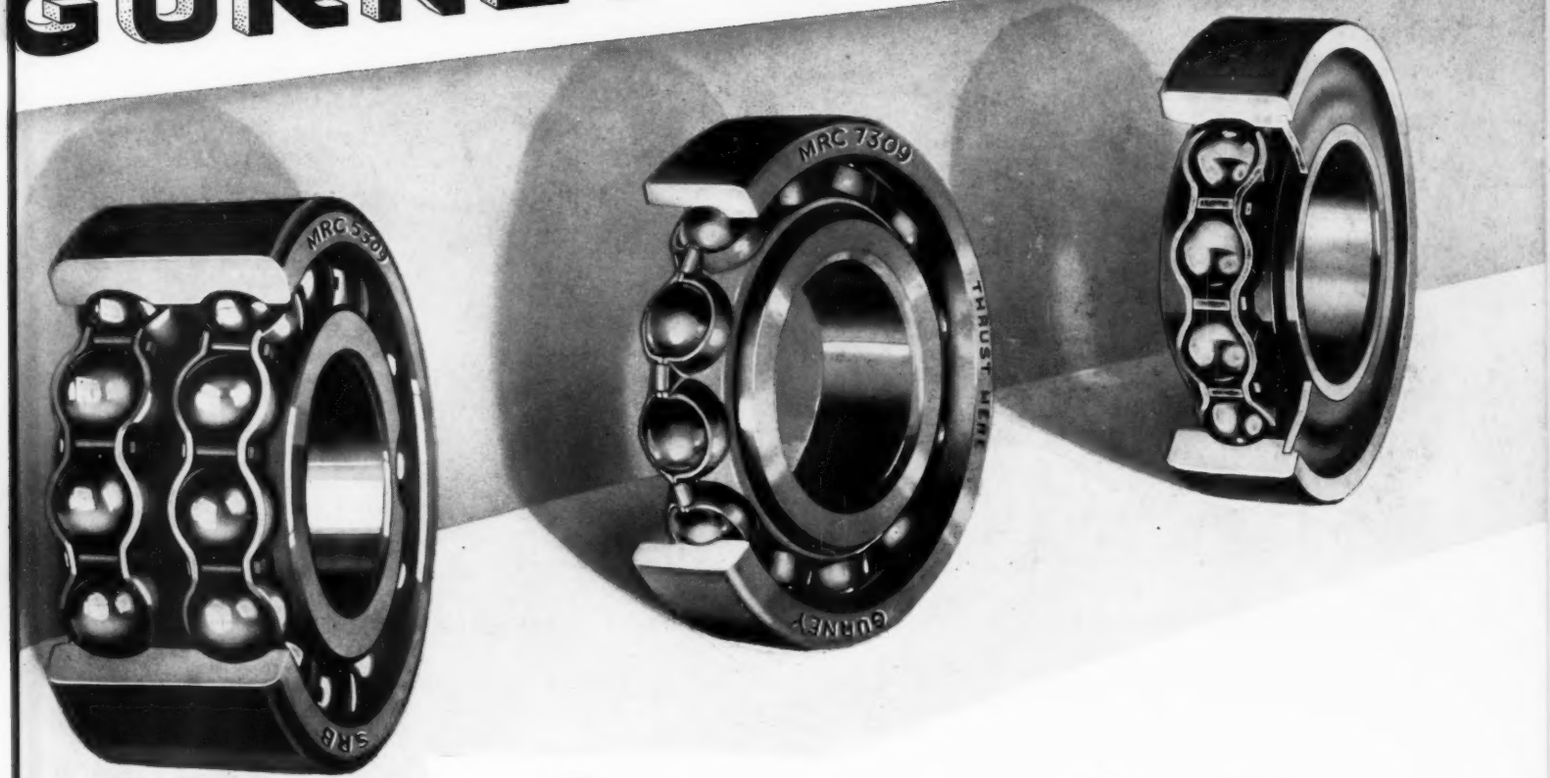
• Modern rail cars are made possible by Goodrich rubber which dampens noise, and absorbs the vibration caused by high speeds.

Goodrich

ALL *products problems* IN RUBBER

M-R-C

GURNEY · SRB · STROM



Leadership . . . On Parade

M-R-C is not merely the name of a line of ball bearings. M-R-C represents the combined experiences, creative talents and engineering abilities of three of the oldest and most reputable makers of bearing equipment in the country—Gurney, SRB and Strom.

Consider this fact in connection with your own bearing requirements. Taken alone, any one of these famous names would certainly merit your consideration. Together, they represent an unquestioned source of all that could be desired in ball bearing performance, dependability and service.

May M-R-C serve you? We are available for engineering advice, suggestions or estimates on any regular or special needs, without obligation.

M-R-C Strom SRB GURNEY BALL BEARINGS

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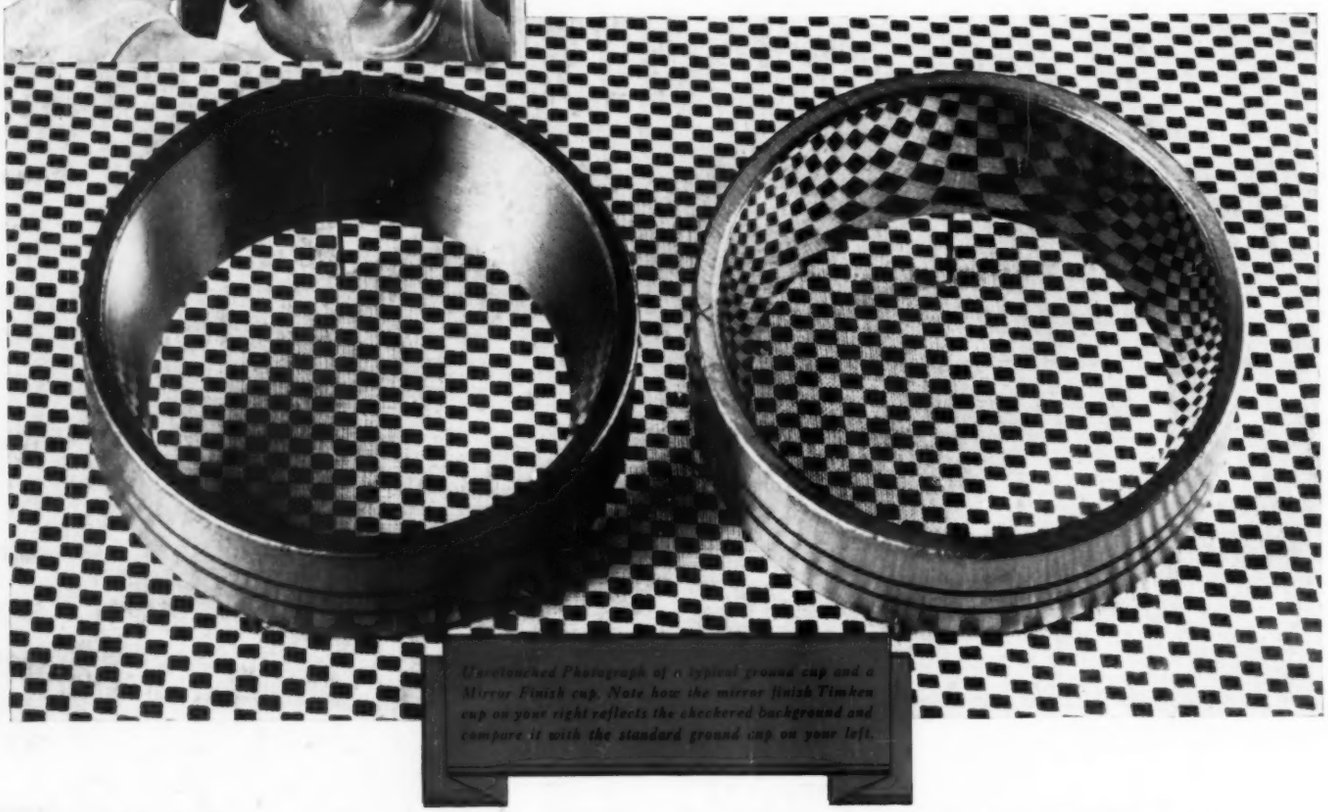
M-R-C BALL BEARINGS

A surface you can see to shave in » »

that's TIMKEN "MIRROR FINISH"



Unretouched Photograph of a typical ground cup and a Mirror Finish cup. Note how the mirror finish Timken cup on your right reflects the checkered background and compare it with the standard ground cup on your left.

"MIRROR FINISH," the amazing new finish developed by Timken for the contact surfaces of Timken Bearings, is all that the name implies. It is by all odds the finest finish ever applied to anti-friction bearings commercially.

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Timken "MIRROR FINISH" is the result of revolutionary advancements in grinding methods, materials, machines and surface measuring instruments. These advancements required years of research and experimentation, and involved hundreds of thousands of tests. Even when compared with the finish previously applied to Timken Bearings—which has always been noted for its fineness—the superiority of Timken "MIRROR FINISH" is instantly apparent.

Outstanding benefits to be expected from Timken "MIRROR FINISH" as applied to Timken Bearings are (1) smoother and quieter operation than has ever been known before. (2) inconceivably slight wear. (3) increased precision. (4) greater lubricating efficiency. (5) longer bearing life.

Timken "MIRROR FINISH" is not yet available in all sizes of Timken Bearings, but its advantages will be extended to our entire production as rapidly as the necessary new equipment can be built and installed.

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

TIMKEN *TAPERED ROLLER* BEARINGS

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